Environmental Studies

U.S. Army Corps
of Engineers

Water Resources Support Center
Institute for Water Resources

Cost Effectiveness Analyis for Environmental Planning:

Nine EASY Steps

U.S. Army Institute for Water Resources
Policy and Special Studies Programs

The Corps of Engineers Institute for Water Resources (CEWRC-IWR) is part of the Water Resources Support Center in Alexandria Virginia. It was created in 1969 to analyze and anticipate changing water resources management conditions, and to develop planning methods and analytical tools to address economic, social, institutional, and environmental needs in water resources planning and policy. Since its inception, IWR has been a leader in the development of tools and strategies to plan and execute Corps water resources planning.

IWR's program emphasizes planning concepts for use by Corps field offices. Initially, this work relied heavily on the experience of highly respected planners and theorists, gained in the many river basin and multiple purpose studies undertaken in the 1060s. As these concepts matured and became a routine part of Corps planning, the emphasis shifted to developing improved methods for conducting economic, social, environmental, and institutional analyses. These methods were essential to implementation of the Water Resources Council's (WRC) Principles and Standards (P&S) and later, Principles and Guidelines (P&G) for water resources planning, which required a multi-objective analysis of and tradeoffs among national, economic, and regional development, environmental quality, and social effects.

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For further information related to the program, call either:

Dr. Eugene Stakhiv
Chief, Policy and Special Studies Division
703-355-2370

Mr. Kyle E. Schilling
Director, Institute for Water Resources
703-355-2015

Department of the Army Corps of Engineers
Water Resources Support Center
Casey Building, 7701 Telegraph Road
Alexandria, VA 22315-3868

Reports may be ordered by writing (above address), calling Arlene Nurthen, IWR Publications, at 703-355-3042, or by fax 703-355-3171.

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Institute for Water Resources
Water Resources Support Center
U.S. Army Corps of Engineers
7701 Telegraph Road
Alexandria, Virginia 22315-3868

Prepared by

Kenneth D. Orth

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"Cost Effectiveness Analysis for Environmental Planning: Nine EASY Steps" was undertaken as a part of the Policy Studies Program conducted by the U.S. Army Corps of Engineers' Institute for Water Resources (IWR). It was prepared in response to the need to develop a simplified analytical procedure to complement the development of new integrated guidance for environmental restoration. Dr. Eugene Z. Stakhiv, Chief of the Policy and Special Studies Division, has long promoted the improvement of analytical techniques for the multiobjective planning process, especially as applied to environmental quality planning; his continuing direction and support were invaluable contributions in the development of this work. Mr. Kyle E. Schilling is the Director of IWR, and Mr. Kenneth H. Murdock is the Director of the Water Resources Support Center.

This paper was prepared by the IWR staff in cooperation with the staff of the Corps of Engineers Headquarters. Mr. Ken Orth, of the IWR Policy and Special Studies Division, was the project manager. Mr. William Hansen, of the IWR Technical Analysis and Research Division, was especially generous with frequent comments and ideas. Valuable contributions were also provided by Ms. Lynn Martin and Messrs. Richard Reppert and Robert Cantave, of the IWR Policy and Special Studies Division; Mr. Ridge Robinson, of the IWR Technical Analysis and Research Division; Mr. Kirby B. Fowler, of the Planning Division, Headquarters; and Messrs. John Belligner, Terry Breyman, and David Reece of the Policy Division, Headquarters. The experience of Mr. Bruce Carlson of the St. Paul District in conducting the Bussey Lake case study for IWR added an immediate reality to this work. Dr. Leonard Shabman, of Virginia Polytechnic Institute and State University, has been a continuing sounding board for IWR and the Corps, and provided a review of this paper.

Many other Corps environmental scientists, economists and planners read and commented on previous versions of this paper. Their struggles to understand and use incremental cost and cost effectiveness analyses in environmental planning have led to many changes in the procedure. Our colleagues' criticisms and insights, as well as their patience, continue to contribute to the evolution and practical application of these tools, and their assistance is appreciated.

TABLE OF CONTENTS

LIST OF EXHIBITS

ABBREVIATIONS

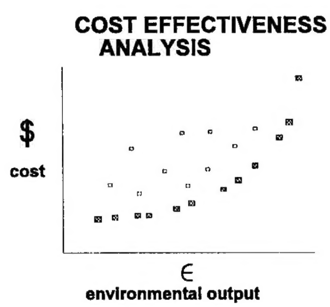
EC	engineer circular
EEIRP	Evaluation of Environmental Investments Research Program
ER	engineer regulation
HEP	Habitat Evaluation Procedures
HU	habitat unit
IWR	Institute for Water Resources
NED	National Economic Development
OMRR&R	operation, maintenance, repair, replacement and rehabilitation
P&G	Principles and Guidelines

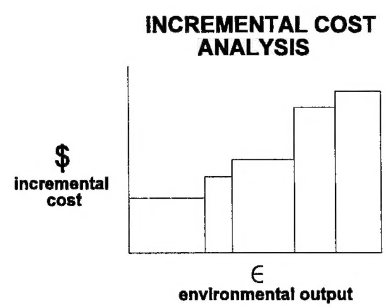
EXECUTIVE SUMMARY

"Cost Effectiveness for Environmental Planning: Nine EASY Steps" was developed to help Corps planners conduct cost effectiveness and incremental cost analyses in planning for environmental restoration and mitigation. It presents step-by-step instructions about how to conduct the analyses, using an example to illustrate their application to a planning problem. Questions and answers based on recent field-level review and experience in environmental planning are also included.

The U.S. Water Resource Council's Principles and Guidelines (1983; called the "P&G") provide the instructions and rules for Federal water resource planning. The P&G require that, in developing alternative plans, Federal planners should "include only increments that provide net NED [National Economic Development] benefits [for flood damage reduction, navigation, and other traditional benefit categories]... Increments that do not provide net NED benefits may be included...if they are cost effective." Corps of Engineers guidance reflects this directive, and requires an incremental cost analysis for recommended environmental restoration and mitigation plans.

Two analytical processes are conducted to meet these requirements in environmental planning. First, **cost effectiveness analysis** is conducted to ensure that the least cost solution is identified for each possible level of environmental output. Subsequent **incremental cost analysis** of the least cost solutions is conducted to reveal changes in costs for increasing levels of environmental outputs. In the absence of a common measurement unit for comparing the non-monetary benefits with the monetary costs of environmental plans, cost effectiveness and incremental cost analyses are valuable tools to assist in decision making.





The value of these analyses is perhaps best illustrated through an example. Suppose that a study has developed three alternative plans for environmental restoration: Plans A, B and C. Plan A will restore 1,000 acres of a habitat at a cost of $1 million; Plan B will restore 950 acres of habitat at a cost of $500,000; and Plan C will also restore 950 acres but at a cost $750,000. While Plans B and C will provide the identical level of environmental output - 950 acres of restored habitat - Plan C is 50% more costly than Plan B. If all others factors are equal, Plan B would be the better choice for restoration. Furthermore, Plan B will provide 95% of Plan A's output at 50% of Plan A's cost. In this case, it would be difficult to argue that the additional 5% of the habitat restored with Plan A would be worth a doubling of the project cost - it is probably far too costly. While this is a simplified and extreme example, it illustrates the type of information revealed through these analyses.

The analytical procedure is presented in nine steps, which may be grouped in four tasks:

- Formulation of combinations:
  - Step 1 - Display outputs and costs.
  - Step 2 - Identify combinable management measures.
  - Step 3 - Calculate outputs and costs of combinations.

- Cost effectiveness analysis:
  - Step 4 - Eliminate economically inefficient solutions.
  - Step 5 - Eliminate economically ineffective solutions.

- Development of incremental cost curve:
  - Step 6 - Calculate average costs.
  - Step 7 - Recalculate average costs for additional output.

- Incremental cost analysis:
  - Step 8 - Calculate incremental costs.
  - Step 9 - Compare successive outputs and incremental costs.

The results of these analyses - displayed as graphs of outputs against costs - permit decision makers to progressively compare alternative levels of environmental outputs and ask if the next level is "**worth it**" - that is, is the additional environmental output in the next level worth its additional monetary cost?

It is important to keep in mind that the most useful information developed by the analyses is what it tells decision makers about the relative relationships among solutions - that one will likely produce greater output than another, or one is likely to be more costly than another - rather than the specific numbers that are calculated. Furthermore, while these analyses will usually not lead, and are not intended to lead, to a single best solution (as in economic cost-benefit analysis) they will improve the quality of decision making by ensuring that a rational, supportable, focused and traceable approach is used for considering and selecting alternative methods to produce environmental outputs.

CHAPTER 1
INTRODUCTION

Purpose.

"Cost Effectiveness for Environmental Planning: Nine EASY Steps" was developed to help Corps planners conduct cost effectiveness and incremental cost analyses in planning for environmental restoration and mitigation. It presents step-by-step instructions about how to conduct the analyses, using an example to illustrate their application to a planning problem. Questions and answers based on recent field-level review and experience in environmental planning are also included. The Corps' official requirements for cost effectiveness and incremental cost analyses are presented in engineer regulation ER 1105-2-100 (U.S. Army Corps of Engineers 1990; referred to as the Planning Guidance Notebook).

This paper was developed to assist anyone who is involved in conducting and using cost effectiveness and incremental cost analyses, particularly those without a background in economics. Additional explanations about the technical aspects of the analyses are presented in the Overview Manual for Conducting National Economic Development Analysis (U.S. Army Corps of Engineers, Institute for Water Resources 1991b).

Requirements.

The Principles and Guidelines (U.S. Water Resources Council 1983; referred to as the "P&G") provide the instructions and rules for Federal water resource planning, and include the following requirement:

> "In general, in the formulation of alternative plans, an effort is made to include only increments that provide net NED benefits after accounting for appropriate mitigation costs... Increments that do not provide net NED benefits may be included, except in the NED plan, if they are cost effective measures for addressing specific concerns." (paragraph 1.6.2 (b))

The Corps of Engineers planning guidance in ER 1105-2-100 (U.S. Army Corps of Engineers 1990) further requires:

> "An incremental cost analysis shall be performed for all recommended mitigation plans. The purpose of incremental cost analysis is to discover and display variation in cost, and to identify and describe the least cost plan." (paragraph 7-35h)

Policy Guidance Letter #24 (U.S. Army Corps of Engineers 1991) extends this requirement to restoration of fish and wildlife habitat resources; and current program and budget guidance accords high priority to "the restoration and protection of environmental resources, including fish and wildlife habitat, i.e. inland and coastal wetlands, other aquatic and riparian habitat, and upland habitat" (U.S. Army Corps of Engineers 1994).

Rationale.

The Corps' requirements for cost effectiveness and incremental cost analyses evolved from the P&G planning paradigm, and reflect its rationale and deliberate approach to solving problems and making decisions. The value of these analyses is perhaps best illustrated through an example.

Suppose that a study has developed and evaluated three alternative plans for environmental restoration: Plans A, B and C. Plan A will restore 1,000 acres of a habitat at a cost of $1 million; Plan B will restore 950 acres of habitat at a cost of $500,000; and Plan C will also restore 950 acres but at a cost $750,000. While Plans B and C will provide the identical level of environmental output - 950 acres of restored habitat - Plan C is 50% more costly than Plan B. If all others factors are equal, Plan B would be the better choice for restoration. Furthermore, Plan B will provide 95% of Plan A's output at 50% of Plan A's cost. In this case, it would be difficult to argue that the additional 5% of the habitat restored with Plan A would be worth a doubling of the project cost - it is probably far too costly. While this is a simplified and extreme example, it illustrates the type of information revealed through cost effectiveness analysis and incremental cost analysis.

For environmental planning, where traditional benefit-cost analysis is not possible because costs and benefits are expressed in different units, cost effectiveness and incremental cost analyses offer approaches that are consistent with the P&G planning paradigm. Cost effectiveness will ensure that the least cost solution is identified for each possible level of environmental output. Subsequent incremental cost analysis will reveal changes in costs for increasing levels of environmental outputs. As recently noted by Dr. Charles Yoe:

> "Incremental cost analysis, while it does not lead to perfect economic or environmental solutions, leads to better solutions because it elevates the decision process above the often emotional cost oblivious arguments" (Yoe 1993).

In a broader planning context, Dr. Leonard Shabman's recent study of the Corps' environmental activities (IWR Report 93-PS-1) described the emergence of a new, negotiation-based decision process wherein environmental "value is established as a consequence of group negotiations in political forums, instead of by individual negotiations in market exchanges". Shabman argues that the Corps' strength in performing analysis should be its contribution to the negotiating parties, noting:

> "The most useful analysis for supporting the negotiation process will be an evaluation of 'net incremental opportunity costs' of restoration. An opportunity cost analysis can be used to address the central question posed by the new emphasis on environmental restoration, 'How much environmental restoration is enough?', where the answer to that question will emerge from a negotiation process which it builds upon foregone NED as the cost information. Continually focusing the restoration question on whether an increment of restoration is 'worth' its cost is the most practical way to answer the question 'how much is a restoration worth?'... [Factual] conflict resolution is an area where planning and evaluation protocols will make their greatest contribution. For the Corps, data analysis and interpretation, along with conceptualization of logical arguments, can be a basic contribution to the planning process -- sound information

is the first step toward settlement of disputes." (U.S. Army Corps of Engineers, Institute for Water Resources 1993b)

Although cost effectiveness and incremental cost analyses will help to reveal such information, it is important to keep in mind that the most useful information developed by the analyses is what it tells decision makers about the relative relationships among solutions - that one will likely produce greater output than another, or one is likely to be more costly than another - rather than the specific numbers that are calculated. Furthermore, while these analyses will usually not lead, and are not intended to lead, to a single best solution (as in economic cost-benefit analysis), they will improve the quality of decision making by ensuring that a rational, supportable, focused and traceable approach is used for considering and selecting alternative methods to produce environmental outputs.

Background.

Over the past decade and a half, the decreasing share of the Federal budget available for discretionary purposes, such as water resources development, led to the need to better explain and justify Federal programs and projects. During this time, the Corps and other Federal agencies found it necessary to establish tighter funding and spending requirements to ensure that limited funds would be used for the best projects at the local level, and for the best mix of worthy projects from a national perspective. One such Corps requirement was for an incremental cost analysis to support decisions for fish and wildlife habitat mitigation.

Benefit-cost analysis, incremental cost analysis and cost effectiveness analysis have long been integral to Federal water resources planning. Traditionally, these analyses have focused on projects' monetary costs and benefits. Cost effectiveness analysis has been the means to identify the least costly means to achieve a range of project benefits; subsequent incremental cost analysis has been used to scale project size by judging whether increasing economic benefits are worth their additional costs.

In the mid-1980's, the Corps adopted the principles of these analyses for use in planning and justifying mitigation for fish and wildlife habitat losses caused by projects for flood control, navigation, and other developmental purposes. Costs for mitigation are essentially the same types of financial costs as are incurred for other project purposes, including costs for: preconstruction engineering and design, real estate, construction, and ongoing operation, maintenance, repair, and rehabilitation.

Benefits for mitigation are more problematic since, unlike flood control, navigation and other developmental purposes, mitigation benefits are not measured monetarily. The analytical difficulty that this presents to justifying environmental projects is so pervasive that the Water Resources Development Act of 1986 sought to legislate a solution. Section 907 of that Act directs that:

> "In the evaluation by the Secretary [of the Army] of benefits and costs of a water resources project, the benefits attributable to measures included in a project for the purpose of environmental quality... shall be deemed to be at least equal to the costs of such measures".

Notwithstanding the intent of the Act, there remains no universally acceptable method to express environmental benefits in exclusively monetary or economic terms. Mitigation of environmental damage can, however, be expressed in other metrics, ranging from simple numbers of acres of a given habitat to more sophisticated indicators like "habitat units". Therefore, although a traditional benefit-cost analysis cannot be conducted without monetary benefits, the financial costs of mitigation plans can be compared with their nonmonetary effects. Such comparison is at the heart of cost effectiveness and incremental cost analyses, and is the basis for their application in environmental planning.

Initial Corps guidance on the applicability of incremental cost analysis in environmental planning was presented in EC 1105-2-185 (U.S. Army Corps of Engineers 1988), which was subsequently incorporated into ER 1105-2-100 (U.S. Army Corps of Engineers 1990). The guidance was limited to analyses for mitigation and to fish and wildlife habitat, and focused on plan formulation and incremental cost analysis:

> "Incremental cost analysis is an investigation and characterization of how the costs of extra units of output increase as the level of output increases. In mitigation planning, such analyses will result in an array of implementable mitigation plan increments, ranked from most to least cost effective" (U.S. Army Corps of Engineers 1988).

Early Corps field-office applications of the guidance frequently consisted of an intuitive calculation and display of the average cost per unit of environmental output ("benefit") for a set of alternative plans. In order to help planners move beyond this approach, the Corps Headquarters tasked IWR to better define how cost effectiveness and incremental cost analyses could be accomplished. IWR first developed an overview, titled Economic and Environmental Considerations for Incremental Cost Analysis in Mitigation Planning (U.S. Army Corps of Engineers, Institute for Water Resources 1991a), and then a draft manual titled Incremental Cost Analysis Primer for Environmental Resources Planning (U.S. Army Corps of Engineers, Institute for Water Resources 1992). These studies provided background research that evolved into the "Nine EASY Steps", which was first distributed as a draft paper in 1993.

Concurrent with this work, IWR supported two field demonstrations to test the applicability of the "Nine EASY Steps" procedure. The first demonstration was at Bussey Lake, Iowa; a 213-acre site where the Corps' St. Paul District was investigating restoration of a riverine backwater fish community. The Bussey Lake analysis used a modified bluegill model (based on the "Habitat Evaluation Procedures", HEP, framework) to measure environmental outputs, and analyzed financial costs and fisheries benefits for 192 combinations of four management measures: aeration, substrate improvement, harvesting and dredging. The results, which are reported in Bussey Lake: Demonstration Study of Incremental Analysis in Environmental Planning (U.S. Army Corps of Engineers, Institute for Water Resources 1993a), illustrate a successful application of the nine-step procedure in a typical small Corps project. A second field demonstration is in progress by the Baltimore District for Kingman Lake along the Anacostia River, Maryland.

Analytical tools are continuing to evolve with the Corps' environmental mission. Over the past few years, the Corps' list of "high priority outputs" eligible for funding requests was expanded from urban flood damage reduction and commercial navigation to include restoration of environmental resources. In 1991, the Corps extended the requirement for incremental cost analysis to such restoration planning (U.S. Army Corps of Engineers 1991). The scope of the mission has also been broadened from localized fish and

wildlife habitats to watershed scale ecosystems. The first applications of cost effectiveness and incremental cost analyses to these new situations are currently being developed.

Future Directions.

IWR is continuing to work toward making future analytical applications easier, quicker and less expensive. A comprehensive procedures manual for cost effectiveness and incremental cost analyses is in the early stages of preparation. The manual, which is expected to be complete in 1995, will consolidate the work and experiences accomplished to date, as well as new understandings and tools. In response to many comments from field practitioners, the manual will include an automated interactive program that will speed calculations and improve the ability to analyze a wide range of alternatives.

The forthcoming manual is being prepared as a part of the Evaluation of Environmental Investments Research Program (EEIRP). This program is a joint effort by IWR and the Waterways Experiment Station to provide Corps planners with methodologies and techniques to aid in developing supportable environmental restoration and mitigation projects and plans. EEIRP will address many issues related to cost effectiveness and incremental cost analyses, including:

- Determining and describing environmental significance.
- Determining objectives and measuring outputs.
- Objective evaluation of cultural resources.
- Engineering environmental investments - Formulating inputs and monitoring effectiveness.
- Cost effectiveness analysis techniques.
- Monetary and other valuation techniques.
- Incorporating risk and uncertainty into environmental evaluation.
- Environmental database and information management.
- Evaluation framework.

The results of the EEIRP research will be provided as they become available; the program is scheduled to be complete in 1997.

In a broader context, the recent National Performance Review (1993a) sets a long-term tone for the entire Federal system, and provides some insight into the future of environmental analyses. The Review states:

> "We must force our government to put the customer first by injecting the dynamics of the marketplace... we can transplant some aspects of the business world into the public arena. We can create an environment that commits federal managers to the same struggle to cut costs and improve customer service that compels private managers."

In the accompanying report on reinventing environmental management, the Review further notes:

> "The key to making better economic and environmental decisions is access to accurate and timely information on environmental costs and benefits. With this information decision makers can evaluate alternatives and determine those which are more environmentally beneficial, as well as more economical. Currently, however, most federal government decision makers do not have access to environmental cost and benefit information". (National Performance Review 1993b)

In a follow-up to the National Performance Review, the President issued Executive Order 12893, Principles for Federal Infrastructure Investments (1994). The Order establishes two investment principles: systematic analysis of expected benefits and costs, and efficient management, requiring that "analyses should consider not only quantifiable measures of benefits and costs, but also qualitative measures reflecting values that are not readily quantified".

Tools such as cost effectiveness and incremental cost analyses are in the spirit of approaches suggested by the National Performance Review, and are some of the means available to implement the principles of Executive Order 12893. Their continuing improvement and use will provide the Corps, other agencies, interest groups and the public with better information on which to base their decisions about our increasingly scarce natural and financial resources.

CHAPTER 2
SUMMARY

Steps and Tasks.

This procedure consists of nine steps:

Step 1 - Display outputs and costs.
Step 2 - Identify combinable management measures.
Step 3 - Calculate outputs and costs of combinations.
Step 4 - Eliminate economically inefficient solutions.
Step 5 - Eliminate economically ineffective solutions.
Step 6 - Calculate average costs.
Step 7 - Recalculate average costs for additional output.
Step 8 - Calculate incremental costs.
Step 9 - Compare successive outputs and incremental costs.

> **How Long Do the Analyses Take, and What Do they Cost?**
>
> See Chapter 4, Question and Answer #3 for a discussion of time and cost considerations.

> **What Level of Detail Is Needed in the Analyses?**
>
> See Chapter 4, Question and Answer #4 for a discussion about how detailed the analyses should be.

The steps can be grouped in four tasks:

Steps 1 - 3: Formulation of combinations.
Steps 4 - 5: Cost effectiveness analysis.
Steps 6 - 7: Development of incremental cost curve.
Steps 8 - 9: Incremental cost analysis.

Formulation of Combinations.

There are many ways to formulate alternative plans. Traditionally in the Corps, alternative plans have been developed using the judgment of technical experts, primarily engineers and architects, who are skilled and experienced in creating ways to solve water resource problems. Plans are usually developed by the Corps' experts, although plans are often given to the Corps by other agencies or interests.

Another way to develop alternative plans is to identify all of the possible **combinations** of a given set of management measures and the measure's increments. This is the approach presented in this procedure. Much like the traditional approach, expert judgment is also necessary in identifying the measures and

measures' increments that are to be combined. However, the process of combining those pieces then proceeds as described in Steps 1 - 3:

Step 1 displays the environmental outputs and cost estimates of the increments of management measures.

Step 2 reviews the management measures to separate those that can be implemented together from those that can't be implemented together.

Step 3 lists all combinations of the combinable management measures' increments, and calculates each combination's output and cost.

Formulation of combinations is one, but not the only, approach to develop a set of alternative plans. Therefore, if you have a set of alternative plans that were formulated using a traditional approach, supplied by others, or evolved through some other method, your analysis may begin at Step 4 of this procedure. The advantage of formulating combinations is that no solution will be overlooked, and the full range of solutions will be included in the analysis.

Cost Effectiveness Analysis.

Cost effectiveness analysis identifies and eliminates **economically irrational** solutions:

Step 4 identifies and eliminates **inefficient** solutions: If you can produce a given level of output in more than one way, only the least expensive choice makes economic sense for that level of output.

Step 5 identifies and eliminates **ineffective** solutions: If you can produce a greater level of output for the same or less cost, then only the greater output choice makes economic sense.

Development of Incremental Cost Curve.

The resulting cost effective solutions may proceed directly to the Step 8 analysis of incremental costs. However, an immediate incremental cost analysis may reveal irregular, non-continuously increasing cost changes (sometimes called "lumpy data") that are uncharacteristic of a classic incremental cost curve. The cost effective solutions can be screened to eliminate such changes by **repeatedly** calculating average costs to progressively identify additional levels of output that can be produced at the lowest average cost:

Step 6 calculates the average costs of the cost effective solutions and identifies the solution with the lowest average cost.

Step 7 repeatedly asks the question: Of the remaining levels of output, which solution has the lowest average cost for additional output?

This screening analysis may tend to eliminate solutions that have lower total costs but are relatively inefficient in production. Although not required, Steps 6 and 7 will eliminate distortions in incremental costs and produce the classic cost curve.

Incremental Cost Analysis.

Incremental cost analysis reveals and interprets changes in costs for increasing levels of environmental outputs:

> **Step 8** calculates incremental costs for the remaining levels of output.
>
> **Step 9** progressively compares successive levels of output and their incremental costs to provide decision makers with information that is useful in addressing the question: Is the environmental output worth its cost?

While the step-by-step instructions may appear mechanical, many questions that bear on the analyses must be struggled with in the context of each unique study and environment: What are the significant environmental resources to be addressed? How should resource changes be measured? What management measures should be considered? How many increments of management measures are needed? What measures can be implemented together in combination? And finally, the basic question that these analyses are directed to: "Is the additional environmental output worth its cost?" Decision makers and analysts - biologists, economists, planners, and others - must always keep in mind that both cost effectiveness and incremental cost analyses require a large measure of cooperation, creative and independent thinking, interpretation and judgment. An interdisciplinary approach is essential in these efforts.

Who Does the Analyses?

See Chapter 4, Question and Answer #1, for a discussion about who conducts cost effectiveness and incremental cost analysis.

What are the Roles of Others?

See Chapter 4, Question and Answer #2, for a discussion of the role of other Federal and State agencies and the local cost sharing sponsor in conducting the analyses

Example.

Application of the step-by-step instructions is illustrated through an example based on management of habitat for a small songbird called a veery. Three management measures that are likely to improve habitat conditions for the veery have been identified for analysis; the measures would be located on Corps land already acquired in fee title:

- Management Measure "**A**" - Plant deciduous shrubs on a 20 acre site to increase shrub crown cover. Seven different planting densities were selected for analysis:

  A_1 - Plant 40 shrubs per acre.
  A_2 - Plant 75 shrubs per acre.
  A_3 - Plant 125 shrubs per acre.
  A_4 - Plant 175 shrubs per acre.
  A_5 - Plant 350 shrubs per acre.
  A_6 - Plant 550 shrubs per acre.
  A_7 - Plant 750 shrubs per acre.

- Management Measure "**B**" - Construct a low-height berm to change an adjacent pond's water elevations as a means of increasing soil moisture. Five different water elevations, requiring different berm sizes, were selected for analysis:

  B_1 - Maintain water elevation at +120.0 feet.
  B_2 - Maintain water elevation at +120.4 feet.
  B_3 - Maintain water elevation at +120.8 feet.
  B_4 - Maintain water elevation at +121.4 feet.
  B_5 - Maintain water elevation at +121.6 feet.

- Management Measure "**C**" - Install a fence around selected areas to protect the natural increase in shrub development and herbaceous cover. Four different fence lengths were selected for analysis:

  C_1 - Install 2,200 linear feet of fence.
  C_2 - Install 3,600 linear feet of fence.
  C_3 - Install 5,000 linear feet of fence.
  C_4 - Install 5,600 linear feet of fence.

This example is for illustration purposes, and is not meant to be inclusive of all of the variables or measures that could or should be considered. It is simplistic, and liberties have been taken to make it easier to follow. Readers and users should focus on the process and points illustrated by the example to improve their understanding of the analytical procedure.

The following instructions use the example to show how information is developed, compared, reviewed and otherwise used, and are extensively illustrated in exhibits of tables and graphs. The exhibits are intended to document the thought process that occurs during the analysis. Report documentation will vary for each analysis, and tables and graphics similar to the exhibits included in this procedure may be helpful. However, none of the exhibits included here are required for any report.

CHAPTER 3
INSTRUCTIONS

Before you begin.

> **Are the Analyses Applicable to Both Mitigation and Restoration?**
>
> See Chapter 4, Question and Answer #11 for a discussion about applicability.

Cost effectiveness and incremental cost analyses combine, sort, compare and interpret information about the environmental outputs and monetary effects of management measures. Therefore, before you begin the analyses, you must have information about:

- Management measures, and each measure's
- Monetary effects and
- Environmental outputs.

The Corps' requirements for the analyses that produce these results are in ER 1105-2-100 (U.S. Army Corps of Engineers 1990). The following is a summary of what's needed to begin cost effectiveness and incremental cost analyses.

Management measures. Initially, a study's planning objectives are used to identify management measures, with the question of: "Given objective X, what are the different things that can be done to meet that objective?" A common approach to answering this question is to consult experts, such as hydraulic design engineers, landscape architects, and wildlife managers, who are knowledgeable about ways to solve particular problems. Resulting management measures - structural and nonstructural, in a variety of sizes and configurations - can then be used as the building blocks of alternative plans. Many strategies can be used to build and shape plans from measures, including the approach of formulating all combinations of measures as described in Steps 1 - 3. The example application that is tracked through these instructions uses three management measures, each with different sized measure increments, as previously described.

Given an initial set of alternative solutions, evaluation follows. Traditionally, evaluation of flood control and navigation solutions largely consisted of developing cost estimates and the economic benefits for the solutions being considered. This produced monetary estimates of costs and benefits that entered an incremental benefit-cost analysis. Solutions' other effects, including environmental and social impacts, were also assessed. However, because these other effects were unintended byproducts of meeting the developmental objectives (flood control and navigation, for example), they played a secondary role of being disclosed and accounted for in decision making, but not included in the analytical process.

Monetary effects. Evaluation of environmental restoration and mitigation solutions also requires an evaluation of monetary effects in three general classes. When combined, these effects form the "cost" information for cost effectiveness and incremental cost analyses:

● Implementation costs, which are costs for construction, real estate, and OMRR&R (operation, maintenance, repair, replacement and rehabilitation). This is the traditional "cost estimate". Monitoring costs should also be included.

● Opportunity costs, which are any existing National Economic Development (NED) benefits that would be given up as a result of implementing environmental solutions, such as the value of water supply storage given up for storage to regulate stream flow through a riparian community.

● Other direct benefits, which are any new NED benefits that would be incidentally and unintentionally produced by environmental solutions, such as the value of flood damage reduction provided by a wetland.

The example application that is tracked through these instructions uses only estimated implementation costs in order to simplify the illustration.

Environmental outputs. The "benefits" from environmental solutions - called "outputs" - are not measured monetarily, but rather in some other unit (or units) indicative of the specific restoration or mitigation planning objective that the solutions are intended to address. Environmental evaluation techniques vary among types of outputs, and range from comparatively simple acreage estimating to complex system models. No single unit of output or measurement technique is applicable for all situations, and an approach must be identified in each unique planning setting. Regardless of the approach taken, the results form the environmental "output" information for cost effectiveness and incremental cost analyses.

Must Habitat Units (HU) Be Used in Analyses?

See Chapter 4, Question and Answer #5 for a discussion about the types of environmental outputs that can be used in the analyses.

Are the Analyses Only Applicable to Fish and Wildlife Species?

See Chapter 4, Question and Answer #6 for a discussion about range of planning concerns that can be addressed through cost effectiveness and incremental cost analyses.

Note that, as described here, environmental "outputs" are a subset of what many practitioners have historically termed environmental "impacts". The difference is that "outputs" are the desired and intended effects of solutions, while "impacts" are the full range of effects, both undesirable and desirable, and unintended and intended.

Furthermore, as in traditional planning, the full range of effects, including other environmental and social impacts, must also be assessed for environmental restoration and mitigation solutions. For example, the impacts of a wetland restoration project on lost upland habitat, displaced upland wildlife, relocated utilities and structures, and other impacts must be assessed.

The example application that is tracked through these instructions uses habitat units (HU) as the measure of environmental output. Other environmental and social impacts of the considered management measures are not presented in order to simplify the illustration.

Once you have identified and sized a set of management measures, and evaluated their monetary effects and environmental outputs, you are ready to begin cost effectiveness and incremental cost analyses.

STEP 1 - DISPLAY OUTPUTS AND COSTS.

Display the environmental outputs (in this case, effects on habitat expressed in habitat units; HU) and the cost estimates (in dollars; $) of the management measures increments. Outputs and costs can be displayed as average annual ("annualized") outputs and costs (for example, average annual habitat units, and average annual equivalent dollars), or total outputs and total costs; either is acceptable so long as they are comparable. **Exhibit Step 1** displays this information in a table format.

What Do You Do When There Is More than One Environmental Output?

See Chapter 4, Question and Answer #7 for a discussion of analyses of multiple and different environmental outputs.

What's an Increment?

See Chapter 4, Question and Answer #8 for a discussion about different types of increments.

Exhibit Step 1 - Outputs and Costs of Management Measure Increments

(1) Management Measures	(2) Management Measure Increments	(3) Outputs (HU)	(4) Costs ($)
No Action	none	0	0
A - plant deciduous shrubs on 20 acre site (to increase shrub crown cover)	1 - plant 40 shrubs per acre	2	6,000
	2 - plant 75 shrubs per acre	4	8,000
	3 - plant 125 shrubs per acre	6	12,000
	4 - plant 175 shrubs per acre	8	17,000
	5 - plant 350 shrubs per acre	13	35,000
	6 - plant 550 shrubs per acre	17	56,000
	7 - plant 750 shrubs per acre	20	75,000
B - construct berm to change water elevations (to increase soil moisture)	1 - maintain water elevation at +120.0 feet	2	3,000
	2 - maintain water elevation at +120.4 feet	6	6,000
	3 - maintain water elevation at +120.8 feet	10	15,000
	4 - maintain water elevation at +121.2 feet	15	50,000
	5 - maintain water elevation at +121.6 feet	20	100,000
C - install fence around selected areas (to protect natural increase in shrub development and herbaceous cover)	1 - install 2,200 linear feet of fence	8	28,000
	2 - install 3,600 linear feet of fence	13	45,500
	3 - install 5,000 linear feet of fence	18	63,000
	4 - install 5,600 linear feet of fence	20	70,000

STEP 2 - IDENTIFY COMBINABLE MANAGEMENT MEASURES.

How Many Increments Are Needed?

See Chapter 4, Question and Answer #9 for a discussion about the number of increments to be analyzed.

Analyze the management measures to separate those that can be implemented together from those that can't be implemented together.

For example, active management actions like planting (management measure A) and construction of a berm for inundation (management measure B) are not compatible with a passive approach that relies on natural revegetation (management measure C). In this example, there is a conflict between an active approach and a passive approach; the approaches are mutually exclusive, that is, one precludes the other. Therefore, neither measure A or B can be implemented in combination with measure C. On the other hand, measures A and B are compatible and could be implemented together to improve different aspects of the habitat. Making determinations about what can and cannot be combined are often complex decisions that require participation by a variety of disciplines, including hydraulic and design engineers, landscape architects, biologists and others with practical knowledge and experience related to the solutions under consideration.

Fencing is a common management practice that is often used in combination with other measures. For the purpose of illustrating this analysis, the example assumes that fencing would only be used to achieve natural revegetation (management measure C), although in practice it could just as easily be used in combination with other measures like planting (management measure A) and inundation (management measure B).

Exhibit Step 2 illustrates the analysis which, for this example, concludes that management measures A and B are combinable; but doing either A alone, or B alone, or any combination of A and B **precludes** doing C, and, therefore, management measure C cannot be combined with either A or B.

Exhibit Step 2 - Ability to Combine Management Measures

(1) Management Measures	Can be combined with:		
	(2) Management Measure A	(3) Management Measure B	(4) Management Measure C
A - plant deciduous shrubs on 20 acre site (to increase shrub crown cover)	---	Yes; A and B are located at adjoining sites; neither would preclude implementation of the other.	No; C would be located within the same site as A, and would employ natural processes and growth rather than managed growth; therefore, C and A are mutually exclusive.
B - construct berm to change water elevations (to increase soil moisture)		---	No; C would be located within the same site as B, and would employ natural processes and growth rather than managed growth; therefore, C and B are mutually exclusive.
C - install fence around selected areas (to protect natural increase in shrub development and herbaceous cover)			---

STEP 3 - CALCULATE OUTPUTS AND COSTS OF COMBINATIONS.

> **Must Every Combination of Increments Be Analyzed?**
>
> See Chapter 4, Question and Answer #10 for a discussion about the number of combinations.

Identify combinations of the combinable management measures' increments, and calculate each combination's output (HU) and cost ($). The number of all possible combinations will be:

$$Y = (i_A + 1) \times (i_B + 1) \times \ldots (i_N + 1)$$

Where:
Y = number of combinations (including "no action")
A, B ... N = management measures A, B, etc. through the last measure N
i_A = number of increments for management measure A.

In some cases the order in which measures or measure increments are undertaken may affect outputs and costs, and A + B may have different results from B + A. The example used here assumes that the order of implementing measures does not change outputs and costs. However, this is not always the case, and the order in which measures are implemented may be a relevant consideration in some analyses.

Exhibit Step 3A presents the results of the calculations in a table format; **Exhibit Step 3B** presents the same information in a slightly different table that will be easier to work with in the next step.

In order to make the example easier to follow, the outputs and costs included in Exhibit Step 3A are simply the sums of the combined measure increments. For example, the output of the combination of A_2 and B_4 was calculated by adding the output of A_2 (4 HU) and the output of B_4 (15 HU), resulting in a combination total ($A_2 + B_4$) of 19 HU. Similarly, the cost of the combination of A_2 and B_4 was calculated by adding the cost of A_2 ($8,000) and the cost of B_4 ($50,000), resulting in a combination total ($A_2 + B_4$) cost of $58,000. While simple addition has been used here, in applying these instructions the **combined totals should not always be calculated as simple sums**, but rather should be estimated using the applicable procedure. In this example, this would mean calculating outputs for the $A_2 + B_4$ combination by again using the same habitat model (the HEP veery model, for example) that was initially used to calculate the individual outputs for A_2 and B_4. Similarly, a cost estimate should be prepared for the $A_2 + B_4$ combination as a single project rather than as two independent pieces. In many cases, you should expect combined outputs and combined costs to be different than the simple sums of the individual measures' increments.

Exhibit Step 3C is the same as Exhibit Step 3B, except that the measure C increments (increments of measures that cannot be combined) have been added at the bottom of the table, thus listing all possible solutions in one table. **Exhibit Step 3D** graphically displays the relationships among all the solutions - combinations of the measure A and B increments, as well as the non-combinable measure C increments (as listed in Exhibit Step 3C) - to visually illustrate the large number and range of choices possible.

Exhibit Step 3A - Outputs and Costs of Combinations

(1) Management Measure A Increments	Management Measure B Increments											
	No B		B_1		B_2		B_3		B_4		B_5	
	(2) Outputs (HU)	(3) Costs ($)	(4) Outputs (HU)	(5) Costs ($)	(6) Outputs (HU)	(7) Costs ($)	(8) Outputs (HU)	(9) Costs ($)	(10) Outputs (HU)	(11) Costs ($)	(12) Outputs (HU)	(13) Costs ($)
No A	0	0	2	3,000	6	6,000	10	15,000	15	50,000	20	100,000
A_1	2	6,000	4	9,000	8	12,000	12	21,000	17	56,000	22	106,000
A_2	4	8,000	6	11,000	10	14,000	14	23,000	19	58,000	24	108,000
A_3	6	12,000	8	15,000	12	18,000	16	27,000	21	62,000	26	112,000
A_4	8	17,000	10	20,000	14	23,000	18	32,000	23	67,000	28	117,000
A_5	13	35,000	15	38,000	19	41,000	23	50,000	28	85,000	33	135,000
A_6	17	56,000	19	59,000	23	62,000	27	71,000	32	106,000	37	156,000
A_7	20	75,000	22	78,000	26	81,000	30	90,000	35	125,000	40	175,000

Exhibit Step 3B - Outputs and Costs of Combinations		
(1) Management Measure Increment Combinations	(2) Outputs (HU)	(3) Costs ($)
No A + No B	0	0
A_1 + No B	2	6,000
A_2 + No B	4	8,000
A_3 + No B	6	12,000
A_4 + No B	8	17,000
A_5 + No B	13	35,000
A_6 + No B	17	56,000
A_7 + No B	20	75,000
No A + B_1	2	3,000
$A_1 + B_1$	4	9,000
$A_2 + B_1$	6	11,000
$A_3 + B_1$	8	15,000
$A_4 + B_1$	10	20,000
$A_5 + B_1$	15	38,000
$A_6 + B_1$	19	59,000
$A_7 + B_1$	22	78,000
No A + B_2	6	6,000
$A_1 + B_2$	8	12,000
$A_2 + B_2$	10	14,000
$A_3 + B_2$	12	18,000
$A_4 + B_2$	14	23,000
$A_5 + B_2$	19	41,000
$A_6 + B_2$	23	62,000
$A_7 + B_2$	26	81,000

Exhibit Step 3B - Continued		
(1) Management Measure Increment Combinations	(2) Outputs (HU)	(3) Costs ($)
No A + B_3	10	15,000
$A_2 + B_3$	14	23,000
$A_3 + B_3$	16	27,000
$A_4 + B_3$	18	32,000
$A_5 + B_3$	23	50,000
$A_6 + B_3$	27	71,000
$A_7 + B_3$	30	90,000
No A + B_4	15	50,000
$A_1 + B_4$	17	56,000
$A_2 + B_4$	19	58,000
$A_3 + B_4$	21	62,000
$A_4 + B_4$	23	67,000
$A_5 + B_4$	28	85,000
$A_6 + B_4$	32	106,000
$A_7 + B_4$	35	125,000
No A + B_5	20	100,000
$A_1 + B_5$	22	106,000
$A_2 + B_5$	24	108,000
$A_3 + B_5$	26	112,000
$A_4 + B_5$	28	117,000
$A_5 + B_5$	33	135,000
$A_6 + B_5$	37	156,000
$A_7 + B_5$	40	175,000

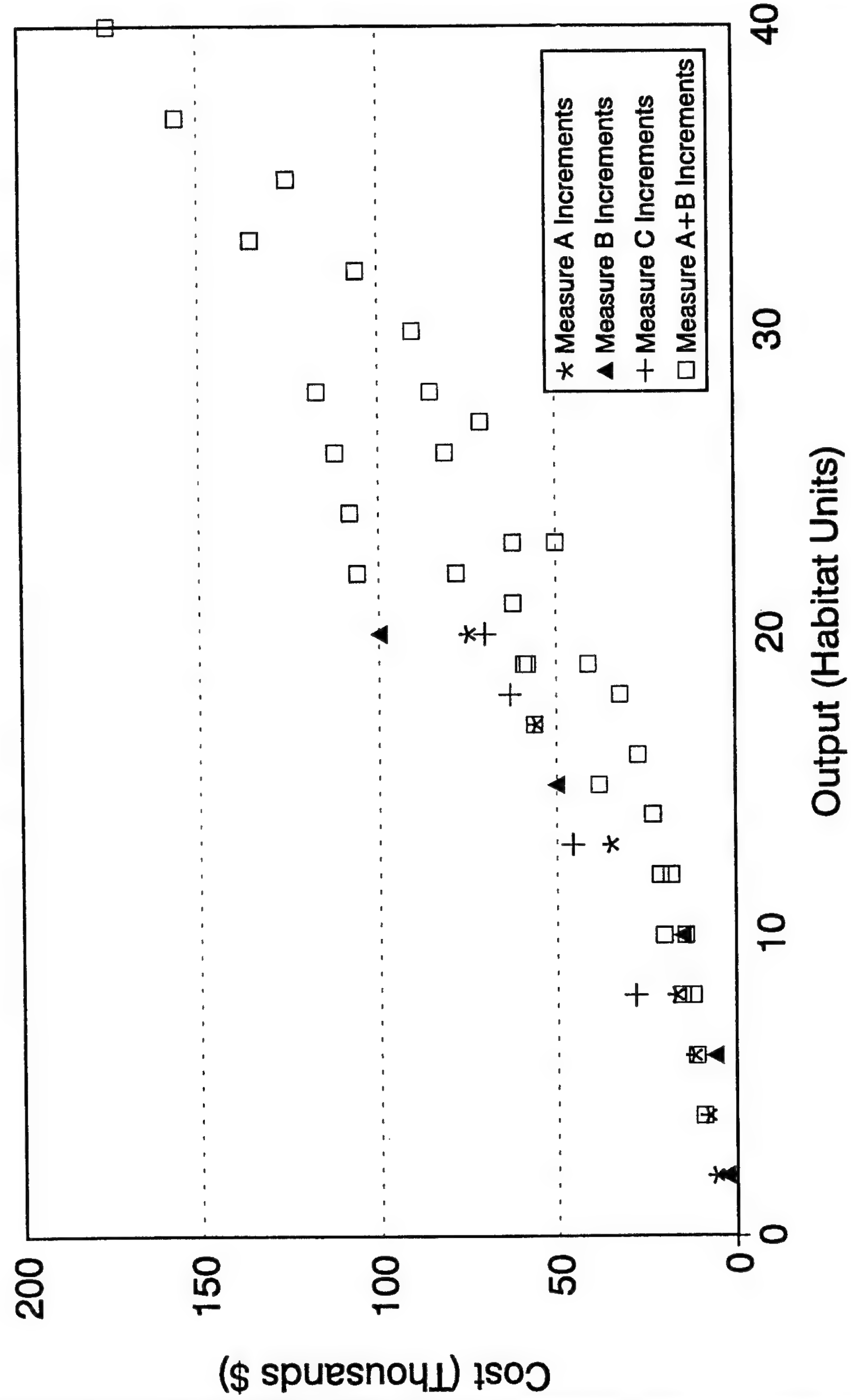
Exhibit Step 3C - Outputs and Costs of All Solutions

(1) Solutions	(2) Outputs (HU)	(3) Costs ($)
No A + No B	0	0
A_1 + No B	2	6,000
A_2 + No B	4	8,000
A_3 + No B	6	12,000
A_4 + No B	8	17,000
A_5 + No B	13	35,000
A_6 + No B	17	56,000
A_7 + No B	20	75,000
No A + B_1	2	3,000
$A_1 + B_1$	4	9,000
$A_2 + B_1$	6	11,000
$A_3 + B_1$	8	15,000
$A_4 + B_1$	10	20,000
$A_5 + B_1$	15	38,000
$A_6 + B_1$	19	59,000
$A_7 + B_1$	22	78,000
No A + B_2	6	6,000
$A_1 + B_2$	8	12,000
$A_2 + B_2$	10	14,000
$A_3 + B_2$	12	18,000
$A_4 + B_2$	14	23,000
$A_5 + B_2$	19	41,000
$A_6 + B_2$	23	62,000
$A_7 + B_2$	26	81,000
No A + B_3	10	15,000
$A_1 + B_3$	12	21,000

Exhibit Step 3C - Continued

(1) Solutions	(2) Outputs (HU)	(3) Costs ($)
$A_2 + B_3$	14	23,000
$A_3 + B_3$	16	27,000
$A_4 + B_3$	18	32,000
$A_5 + B_3$	23	50,000
$A_6 + B_3$	27	71,000
$A_7 + B_3$	30	90,000
No A + B_4	15	50,000
$A_1 + B_4$	17	56,000
$A_2 + B_4$	19	58,000
$A_3 + B_4$	21	62,000
$A_4 + B_4$	23	67,000
$A_5 + B_4$	28	85,000
$A_6 + B_4$	32	106,000
$A_7 + B_4$	35	125,000
No A + B_5	20	100,000
$A_1 + B_5$	22	106,000
$A_2 + B_5$	24	108,000
$A_3 + B_5$	26	112,000
$A_4 + B_5$	28	117,000
$A_5 + B_5$	33	135,000
$A_6 + B_5$	37	156,000
$A_7 + B_5$	40	175,000
C_1	8	28,000
C_2	13	45,500
C_3	18	63,000
C_4	20	70,000

Exhibit Step 3D
Outputs and Costs of all Solutions



STEP 4 - ELIMINATE ECONOMICALLY INEFFICIENT SOLUTIONS.

Reorder the list of solutions (as listed in Exhibit Step 3C) so that they are listed in ascending order of their outputs (0 HU, 1 HU, 2 HU...); and, where two or more solutions produce the same output, in ascending order of their costs. **Exhibit Step 4A** presents the same information as Exhibit Step 3C in this reordered manner.

For each level of output, identify the least cost solution. For example, in Exhibit Step 4A, the smallest level of output that would be produced by any solution is 2 HU, which would be produced by two different solutions: No A + B_1 and A_1 + No B. The first solution (No A + B_1) would produce 2 HU at a cost of $3,000, while the second solution (A_1 + No B) would produce 2 HU at a cost of $6,000. It would not make sense to spend $6,000 for the second solution when the first solution will provide the same level of output at the lesser cost of $3,000. Based on this comparison, the second solution is economically inefficient and should not be included in further analysis.

Exhibit Step 4B is the same as Exhibit Step 4A, except shading was added over the solutions that are economically inefficient - the **not** least cost - solutions. **Exhibit Step 4C** is the same as Exhibit Step 4B except that the shaded (the not least cost) solutions are no longer listed, and only the least cost solution for each level of output is displayed.

In Exhibit Step 4B, there are two instances where two solutions have the same outputs and costs. Solution $A_2 + B_3$ and solution $A_4 + B_2$ would both produce 14 HU at a cost of $23,000. Similarly, solution $A_1 + B_4$ and solution A_6 + No B would both produce 17 HU at a cost of $56,000. Where more than one solution has the same output and cost, the analysis can be simplified by retaining only one solution for further analysis. This simplification was used in Exhibit Step 4C, where solution $A_2 + B_3$ was retained to represent 14 HU at a cost of $23,000, and solution $A_1 + B_4$ was retained to represent 17 HU at a cost of $56,000. While this simplification will not harm the analysis, it is important to remember that the selected solution also represents at least one other solution. At the conclusion of the analysis, both solutions should be presented because, although both have the same effects, the fact that there are different ways to get the same results may be important to decision makers.

Exhibit Step 4A - Outputs and Costs of Solutions, Listed in Ascending Order of Outputs, Then in Ascending Order of Costs If Outputs Are Equal

(1) Solutions	(2) Outputs (HU)	(3) Costs ($)
No A + No B	0	0
No A + B_1	2	3,000
A_1 + No B	2	6,000
A_2 + No B	4	8,000
$A_1 + B_1$	4	9,000
No A + B_2	6	6,000
$A_2 + B_1$	6	11,000
A_3 + No B	6	12,000
$A_1 + B_2$	8	12,000
$A_3 + B_1$	8	15,000
A_4 + No B	8	17,000
C_1	8	28,000
$A_2 + B_2$	10	14,000
No A + B_3	10	15,000
$A_4 + B_1$	10	20,000
$A_3 + B_2$	12	18,000
$A_1 + B_3$	12	21,000
A_5 + No B	13	35,000
C_2	13	45,500
$A_2 + B_3$	14	23,000
$A_4 + B_2$	14	23,000
$A_5 + B_1$	15	38,000
No A + B_4	15	50,000
$A_3 + B_3$	16	27,000
$A_1 + B_4$	17	56,000
A_6 + No B	17	56,000

Exhibit Step 4A - Continued

(1) Solutions	(2) Outputs (HU)	(3) Costs ($)
$A_4 + B_3$	18	32,000
C_3	18	63,000
$A_5 + B_2$	19	41,000
$A_2 + B_4$	19	58,000
$A_6 + B_1$	19	59,000
C_4	20	70,000
A_7 + No B	20	75,000
No A + B_5	20	100,000
$A_3 + B_4$	21	62,000
$A_7 + B_1$	22	78,000
$A_1 + B_5$	22	106,000
$A_5 + B_3$	23	50,000
$A_6 + B_2$	23	62,000
$A_4 + B_4$	23	67,000
$A_2 + B_5$	24	108,000
$A_7 + B_2$	26	81,000
$A_3 + B_5$	26	112,000
$A_6 + B_3$	27	71,000
$A_5 + B_4$	28	85,000
$A_4 + B_5$	28	117,000
$A_7 + B_3$	30	90,000
$A_6 + B_4$	32	106,000
$A_5 + B_5$	33	135,000
$A_7 + B_4$	35	125,000
$A_6 + B_5$	37	156,000
$A_7 + B_5$	40	175,000

Exhibit Step 4B - Outputs and Costs of Solutions, With Shading Over Solutions That Are Not Least Cost Solutions for Each Level of Output

(1) Solutions	(2) Outputs (HU)	(3) Costs ($)
No A + No B	0	0
No A + B_1	2	3,000
A_1 + No B	2	6,000
A_2 + No B	4	8,000
$A_1 + B_1$	4	9,000
No A + B_2	6	6,000
$A_2 + B_1$	6	11,000
A_3 + No B	6	12,000
$A_1 + B_2$	8	12,000
$A_3 + B_1$	8	15,000
A_4 + No B	8	17,000
C_1	8	28,000
$A_2 + B_2$	10	14,000
No A + B_3	10	15,000
$A_4 + B_1$	10	20,000
$A_3 + B_2$	12	18,000
$A_1 + B_3$	12	21,000
A_5 + No B	13	35,000
C_2	13	45,500
$A_2 + B_3$	14	23,000
$A_4 + B_2$	14	23,000
$A_5 + B_1$	15	38,000
No A + B_4	15	50,000
$A_3 + B_3$	16	27,000
$A_1 + B_4$	17	56,000
A_6 + No B	17	56,000

Exhibit Step 4B -Continued

(1) Solutions	(2) Outputs (HU)	(3) Costs ($)
$A_4 + B_3$	18	32,000
C_3	18	63,000
$A_5 + B_2$	19	41,000
$A_2 + B_4$	19	58,000
$A_6 + B_1$	19	59,000
C_4	20	70,000
A_7 + No B	20	75,000
No A + B_5	20	100,000
$A_3 + B_4$	21	62,000
$A_7 + B_1$	22	78,000
$A_1 + B_5$	22	106,000
$A_5 + B_3$	23	50,000
$A_6 + B_2$	23	62,000
$A_4 + B_4$	23	67,000
$A_2 + B_5$	24	108,000
$A_7 + B_2$	26	81,000
$A_3 + B_5$	26	112,000
$A_6 + B_3$	27	71,000
$A_5 + B_4$	28	85,000
$A_4 + B_5$	28	117,000
$A_7 + B_3$	30	90,000
$A_6 + B_4$	32	106,000
$A_5 + B_5$	33	135,000
$A_7 + B_4$	35	125,000
$A_6 + B_5$	37	156,000
$A_7 + B_5$	40	175,000

Exhibit Step 4C - Outputs and Costs of Least Cost Solutions for Each Level of Output

(1) Solutions	(2) Outputs (HU)	(3) Costs ($)
No A + No B	0	0
No A + B_1	2	3,000
A_2 + No B	4	8,000
No A + B_2	6	6,000
$A_1 + B_2$	8	12,000
$A_2 + B_2$	10	14,000
$A_3 + B_2$	12	18,000
A_5 + No B	13	35,000
$A_2 + B_3$	14	23,000
$A_5 + B_1$	15	38,000
$A_3 + B_3$	16	27,000
$A_1 + B_4$	17	56,000
$A_4 + B_3$	18	32,000
$A_5 + B_2$	19	41,000
C_4	20	70,000
$A_3 + B_4$	21	62,000
$A_7 + B_1$	22	78,000
$A_5 + B_3$	23	50,000
$A_2 + B_5$	24	108,000
$A_7 + B_2$	26	81,000
$A_6 + B_3$	27	71,000
$A_5 + B_4$	28	85,000
$A_7 + B_3$	30	90,000
$A_6 + B_4$	32	106,000
$A_5 + B_5$	33	135,000
$A_7 + B_4$	35	125,000
$A_6 + B_5$	37	156,000
$A_7 + B_5$	40	175,000

STEP 5 - ELIMINATE ECONOMICALLY INEFFECTIVE SOLUTIONS.

Conduct a pair-wise comparison of outputs and costs (in Exhibit Step 4C) to identify and delete those solutions that will produce less output at equal or greater cost than subsequently ranked solutions.

For example, in Exhibit Step 4C, the first level of output (2 HU) is produced at a cost of $3,000, the second level of output (4 HU) is produced at a cost of $8,000, and the third level of output (6 HU) is produced at a cost of $6,000. Assuming that initially it makes sense to spend $3,000 to produce 2 HU, it does not make sense to spend $8,000 to produce 4 HU when the next greater level of output (6 HU) can be produced at a lesser cost ($6,000) - why would you spend $8,000 for only 4 HU when you can get 6 HU for $6,000? Based on this comparison, the second solution (A_2 + No B), which produces 4 HU at a cost of $8,000, is economically ineffective and should not be included in further analysis.

Exhibit Step 5A is the same as Exhibit Step 4C, except that shading was added over the economically ineffective solutions. **Exhibit Step 5B** is the same as Exhibit Step 5A, except that the shaded (economically ineffective) solutions are no longer listed and only the efficient solutions are displayed. **Exhibit Step 5C** is the same as Exhibit Step 5B, except that shorthand names were given to each remaining solutions (S_1, S_2,...) in Column 1, and descriptions were added in Column 3 (from Exhibit Step 1, Column 2).

Exhibit Step 5D, the "cost effectiveness frontier", graphically displays the relationships among the remaining solutions. Compare this display with Exhibit Step 3D and note the reduction in the number of solutions.

Exhibit Step 5D shows that, in this example, for any given level of output, a combination of measure A and B increments (points S_1 through S_{17}) is the least cost means to produce that level of output. Note that the management measure C increments were dropped in the analysis of inefficient and ineffective solutions (Steps 4 and 5).

At the completion of Step 5, the cost effectiveness analysis has eliminated the economically inefficient and ineffective management measures and measure combinations. Exhibit Step 5D displays the remaining levels of output for the considered measures. For each remaining level of output, it indicates that at least one solution is available to produce that output; and, if more than one solution would produce that level of output, only the least costly solution has been retained.

Exhibit Step 5A - Outputs and Costs of Least Cost Solutions for Each Level of Output, With Shading Over Ineffective Solutions

(1) Solutions	(2) Outputs (HU)	(3) Costs ($)
No A + No B	0	0
No A + B_1	2	3,000
A_2 + No B	4	8,000
No A + B_2	6	6,000
$A_1 + B_2$	8	12,000
$A_2 + B_2$	10	14,000
$A_3 + B_2$	12	18,000
A_5 + No B	13	35,000
$A_2 + B_3$	14	23,000
$A_5 + B_1$	15	38,000
$A_3 + B_3$	16	27,000
$A_1 + B_4$	17	56,000
$A_4 + B_3$	18	32,000
$A_5 + B_2$	19	41,000
C_4	20	70,000
$A_3 + B_4$	21	62,000
$A_7 + B_1$	22	78,000
$A_5 + B_3$	23	50,000
$A_2 + B_5$	24	108,000
$A_7 + B_2$	26	81,000
$A_6 + B_3$	27	71,000
$A_5 + B_4$	28	85,000
$A_7 + B_3$	30	90,000
$A_6 + B_4$	32	106,000
$A_5 + B_5$	33	135,000
$A_7 + B_4$	35	125,000
$A_6 + B_5$	37	156,000
$A_7 + B_5$	40	175,000

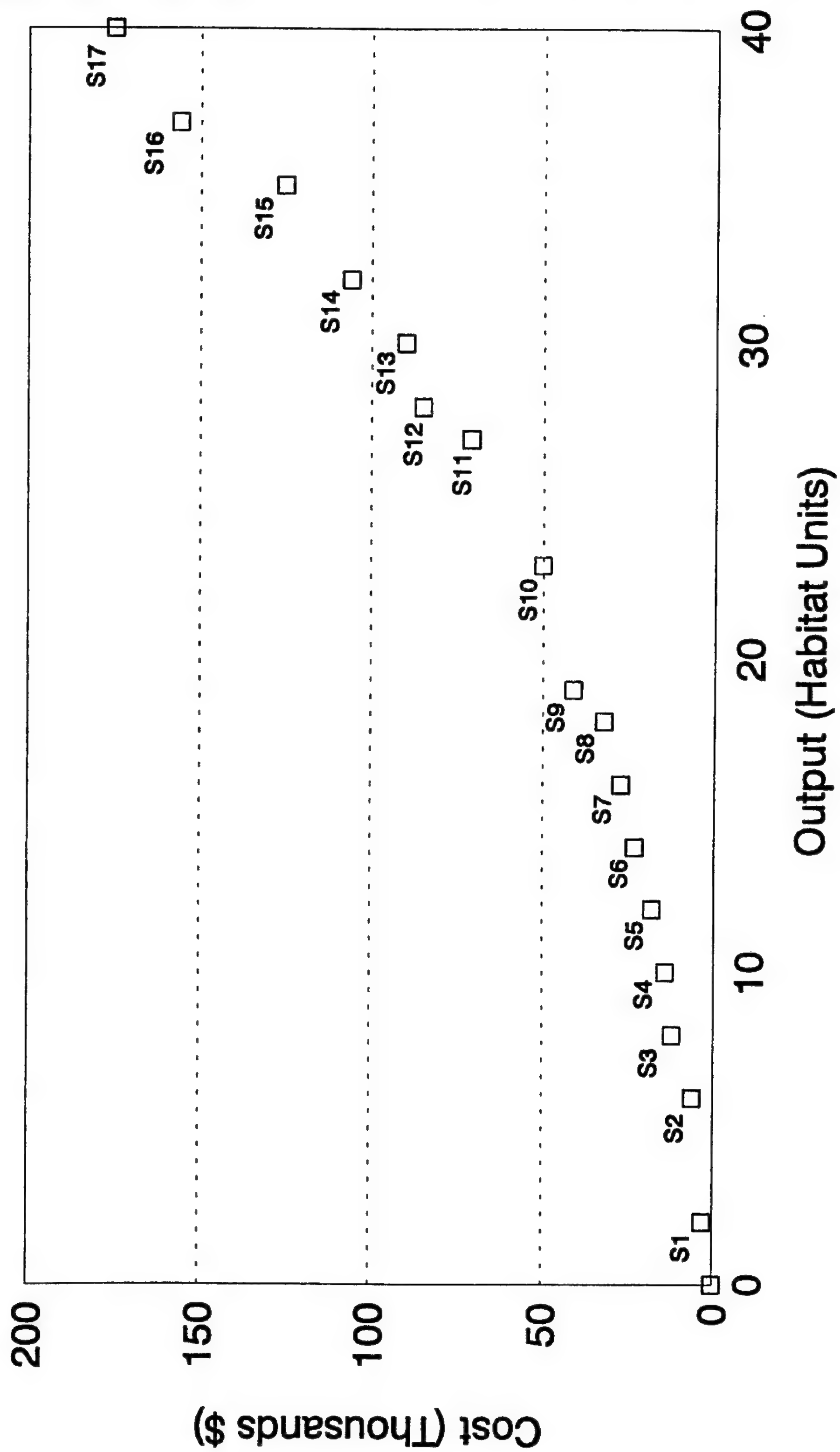
Exhibit Step 5B - Outputs and Costs of Cost-Effective Least Cost Solutions for Each Level of Output		
(1) Solutions	(2) Outputs (HU)	(3) Costs ($)
No A + No B	0	0
No A + B_1	2	3,000
No A + B_2	6	6,000
A_1 + B_2	8	12,000
A_2 + B_2	10	14,000
A_3 + B_2	12	18,000
A_2 + B_3	14	23,000
A_3 + B_3	16	27,000
A_4 + B_3	18	32,000
A_5 + B_2	19	41,000
A_5 + B_3	23	50,000
A_6 + B_3	27	71,000
A_5 + B_4	28	85,000
A_7 + B_3	30	90,000
A_6 + B_4	32	106,000
A_7 + B_4	35	125,000
A_8 + B_5	37	156,000
A_7 + B_5	40	175,000

Exhibit Step 5C - Cost Effective and Least Cost Solutions

(1) Name of Solution	(2) Component Management Measure Increments	(3) Description	(4) Outputs (HU)	(5) Costs ($)
No Action	No A + No B	no action	0	0
S_1	No A + B_1	maintain water elevation at +120.0 feet	2	3,000
S_2	No A + B_2	maintain water elevation at +120.4 feet	6	6,000
S_3	A_1 + B_2	plant 40 shrubs per acre, and, maintain water elevation at +120.4 feet	8	12,000
S_4	A_2 + B_2	plant 75 shrubs per acre, and, maintain water elevation at +120.4 feet	10	14,000
S_5	A_3 + B_2	plant 125 shrubs per acre, and, maintain water elevation at +120.4 feet	12	18,000
S_6	A_2 + B_3	plant 75 shrubs per acre, and, maintain water elevation at +120.8 feet	14	23,000
S_7	A_3 + B_3	plant 125 shrubs per acre, and, maintain water elevation at +120.8 feet	16	27,000
S_8	A_4 + B_3	plant 175 shrubs per acre, and, maintain water elevation at +120.8 feet	18	32,000
S_9	A_5 + B_2	plant 350 shrubs per acre, and, maintain water elevation at +120.4 feet	19	41,000
S_{10}	A_5 + B_3	plant 350 shrubs per acre, and, maintain water elevation at +120.8 feet	23	50,000
S_{11}	A_6 + B_3	plant 550 shrubs per acre, and, maintain water elevation at +120.8 feet	27	71,000
S_{12}	A_5 + B_4	plant 350 shrubs per acre, and, maintain water elevation at +121.2 feet	28	85,000
S_{13}	A_7 + B_3	plant 750 shrubs per acre, and, maintain water elevation at +120.8 feet	30	90,000
S_{14}	A_6 + B_4	plant 550 shrubs per acre, and, maintain water elevation at +121.2 feet	32	106,000
S_{15}	A_7 + B_4	plant 750 shrubs per acre, and, maintain water elevation at +121.2 feet	35	125,000
S_{16}	A_6 + B_5	plant 550 shrubs per acre, and, maintain water elevation at +121.6 feet	37	156,000
S_{17}	A_7 + B_5	plant 750 shrubs per acre, and, maintain water elevation at +121.6 feet	40	175,000

Exhibit Step 5D

Cost Effective and Least Cost Solutions



STEP 6 - CALCULATE AVERAGE COSTS.

Using the set of solutions that emerged from the cost effectiveness analysis (Step 5), calculate average costs by dividing each level of output's cost by its output. The calculation can be expressed as:

$$AC_X = \frac{C_X}{O_X}$$

Where:

X = an increment, either of output, a measure, or a plan
AC_X = average cost of X
C_X = cost of X
O_X = output of X

Exhibit Step 6 is a supply schedule of the average costs for the levels of output used in the example (as listed in Exhibit Step 5C).

Review the average costs and identify the lowest average cost. In Exhibit Step 6, the lowest average cost is $1,000 per HU for the output level of 6 HU. The line for 6 HU has been shaded in Exhibit Step 6 to indicate that it has the lowest average cost. Levels of output less than the lowest average cost level (0 HU and 2 HU in this example) are dropped from further analysis; while levels of output greater than the lowest average cost level (8 HU and greater in this example) advance to the next step.

Note that although you may conduct a pair-wise comparison of the outputs and costs in Exhibit Step 6 to identify and delete those solutions that will produce less output at equal or greater average cost than subsequently ranked solutions (as in Step 5), such a procedure will not eliminate the irregular, non-continuously increasing cost changes that are uncharacteristic of an incremental cost curve.

Exhibit Step 6 - Average Cost of Each Level of Output

(1) Output (HU)	(2) Cost ($)	(3) Average Cost ($ per HU)
0	0	---
2	3,000	1,500
6	6,000	1,000
8	12,000	1,500
10	14,000	1,400
12	18,000	1,500
14	23,000	1,643
16	27,000	1,688
18	32,000	1,778
19	41,000	2,158
23	50,000	2,174
27	71,000	2,630
28	85,000	3,036
30	90,000	3,000
32	106,000	3,313
35	125,000	3,571
37	156,000	4,216
40	175,000	4,375

STEP 7 - RECALCULATE AVERAGE COSTS FOR ADDITIONAL OUTPUT

This step begins with and repeatedly asks the question: Of the remaining levels of output, which level has the lowest average cost for additional output?

Using levels of output remaining from Step 6, calculate the average costs for additional output. These calculations begin with the previous step's lowest average cost level of output as the "zero level". While the calculation in Step 6 produced an average cost based on dividing cost by output; the calculation in this step uses the **additional costs and additional outputs** above those of the previously identified level of output with the lowest average cost.

Exhibit Step 7A displays the outputs and costs of the remaining levels of output (6 HU and greater) in Columns 1 and 3, respectively. The additional outputs and costs of those remaining levels - that is, the outputs and costs beyond those of the 6 HU level of output - are in Columns 2 and 4, respectively. For example, the additional output of the 8 HU level of output is 2 HU (in addition to the 6 HU); the additional output of the 10 HU level of output is 4 HU (in addition to the 6 HU); and so forth. Similarly, the additional cost of the 8 HU level of output is $6,000 (in addition to the $6,000 cost for 6 HU); the additional cost of the 10 HU level of output is $8,000 (in addition to the $6,000 cost for 6 HU); and so forth. Column 5 displays the average costs for additional output for the remaining levels of output, which were calculated by dividing each level's additional cost by its additional output (Column 4 cost divided by Column 2 output).

Again review the average costs for additional output and identify the lowest average cost. In Exhibit Step 7A, the lowest average cost for additional output is $2,000 per HU for two output levels -10 HU and 12 HU. In cases where two or more levels of output share the same average cost, and that cost is the lowest average cost, the greatest level of output is selected - 12 HU in this example. The line for 12 HU has been shaded in Exhibit Step 7A to indicate that it has the lowest average cost for additional output.

Levels of output less than the lowest average cost level (6 HU through 10 HU in this example) are dropped from further analysis; while levels of output greater than the lowest average cost level (14 HU and greater in this example) advance to the next recalculation.

Repeat the Step 7 process (recalculate average costs for additional output, identify lowest average cost, drop levels of output less than lowest average cost) until the final level of output (40 HU in this example) is identified as the lowest average cost level of output. In this example, seven repetitions after the first recalculation (Exhibit Step 7A) were needed to identify 40 HU as the lowest average cost level of output. These repetitions are displayed in:

Exhibit Step 7B - second recalculation
Exhibit Step 7C - third recalculation
Exhibit Step 7D - fourth recalculation
Exhibit Step 7E - fifth recalculation
Exhibit Step 7F - sixth recalculation
Exhibit Step 7G - seventh recalculation
Exhibit Step 7H - eighth recalculation

In each exhibit, shading has been placed over the remaining level of output with the lowest average cost for additional output.

Exhibit Step 7I is a summary of the results of the original calculation of average costs (from Exhibit Step 6) and the subsequent recalculations (from Exhibits Step 7A through 7H). The lowest average cost for additional output is shaded in each column of calculation results. **Exhibit Step 7J** describes the remaining solutions that were identified by this step.

Exhibit Step 7A - Average Cost for Additional Output, First Recalculation

(1) Output (HU)	(2) Additional Output (HU)	(3) Cost ($)	(4) Additional Cost ($)	(5) Average Cost for Additional Output ($ per HU)
6	0	6,000	0	---
8	2	12,000	6,000	3,000
10	4	14,000	8,000	2,000
12	6	18,000	12,000	2,000
14	8	23,000	17,000	2,125
16	10	27,000	21,000	2,100
18	12	32,000	26,000	2,167
19	13	41,000	35,000	2,692
23	17	50,000	44,000	2,588
27	21	71,000	65,000	3,095
28	22	85,000	79,000	3,591
30	24	90,000	84,000	3,500
32	26	106,000	100,000	3,846
35	29	125,000	119,000	4,103
37	31	156,000	150,000	4,839
40	34	175,000	169,000	4,971

Exhibit Step 7B - Average Cost for Additional Output, Second Recalculation

(1) Output (HU)	(2) Additional Output (HU)	(3) Cost ($)	(4) Additional Cost ($)	(5) Average Cost for Additional Output ($ per HU)
12	0	18,000	0	---
14	2	23,000	5,000	2,500
16	4	27,000	9,000	2,250
18	6	32,000	14,000	2,333
19	7	41,000	23,000	3,286
23	11	50,000	32,000	2,909
27	15	71,000	53,000	3,533
28	16	85,000	67,000	4,188
30	18	90,000	72,000	4,000
32	20	106,000	88,000	4,400
35	23	125,000	107,000	4,652
37	25	156,000	138,000	5,520
40	28	175,000	157,000	5,607

Exhibit Step 7C - Average Cost for Additional Output, Third Recalculation

(1) Output (HU)	(2) Additional Output (HU)	(3) Cost ($)	(4) Additional Cost ($)	(5) Average Cost for Additional Output ($ per HU)
16	0	27,000	0	---
18	2	32,000	5,000	2,500
19	3	41,000	14,000	4,667
23	7	50,000	23,000	3,286
27	11	71,000	44,000	4,000
28	12	85,000	58,000	4,833
30	14	90,000	63,000	4,500
32	16	106,000	79,000	4,938
35	19	125,000	98,000	5,158
37	21	156,000	129,000	6,143
40	26	175,000	148,000	6,167

Exhibit Step 7D - Average Cost for Additional Output, Fourth Recalculation

(1) Output (HU)	(2) Additional Output (HU)	(3) Cost ($)	(4) Additional Cost ($)	(5) Average Cost for Additional Output ($ per HU)
18	0	32,000	0	---
19	1	41,000	9,000	9,000
23	5	50,000	18,000	3,600
27	9	71,000	39,000	4,333
28	10	85,000	53,000	5,300
30	12	90,000	58,000	4,833
32	14	106,000	74,000	5,286
35	17	125,000	93,000	5,471
37	19	156,000	124,000	6,526
40	22	175,000	143,000	6,810

Exhibit Step 7E - Average Cost for Additional Output, Fifth Recalculation

(1) Output (HU)	(2) Additional Output (HU)	(3) Cost ($)	(4) Additional Cost ($)	(5) Average Cost for Additional Output ($ per HU)
23	0	50,000	0	---
27	4	71,000	21,000	5,250
28	5	85,000	35,000	7,000
30	7	90,000	40,000	5,714
32	9	106,000	56,000	6,222
35	12	125,000	75,000	6,250
37	14	156,000	106,000	7,571
40	17	175,000	125,000	7,353

Exhibit Step 7F - Average Cost for Additional Output, Sixth Recalculation

(1) Output (HU)	(2) Additional Output (HU)	(3) Cost ($)	(4) Additional Cost ($)	(5) Average Cost for Additional Output ($ per HU)
27	0	71,000	0	---
28	1	85,000	14,000	14,000
30	3	90,000	19,000	6,300
32	5	106,000	35,000	7,000
35	8	125,000	54,000	6,750
37	10	156,000	85,000	8,500
40	13	175,000	104,000	8,000

Exhibit Step 7G - Average Cost for Additional Output, Seventh Recalculation

(1) Output (HU)	(2) Additional Output (HU)	(3) Cost ($)	(4) Additional Cost ($)	(5) Average Cost for Additional Output ($ per HU)
30	0	90,000	0	---
32	2	106,000	16,000	8,000
35	5	125,000	35,000	7,000
37	7	156,000	66,000	9,429
40	10	175,000	85,000	8,500

Exhibit Step 7H - Average Cost for Additional Output, Eighth Recalculation

(1) Output (HU)	(2) Additional Output (HU)	(3) Cost ($)	(4) Additional Cost ($)	(5) Average Cost for Additional Output ($ per HU)
35	0	125,000	0	---
37	2	156,000	31,000	15,500
40	5	175,000	50,000	10,000

Exhibit Step 7I - Summary of Results

(1) Output (HU)	(2) Average Cost for Additional Output in Each Recalculation ($ per HU)								
	(a) original (see Exhibit Step 6)	(b) first (see Exhibit Step 7A)	(c) second (see Exhibit Step 7B)	(d) third (see Exhibit Step 7C)	(e) fourth (see Exhibit Step 7D)	(f) fifth (see Exhibit Step 7E)	(g) sixth (see Exhibit Step 7F)	(h) seventh (see Exhibit Step 7G)	(i) eighth (see Exhibit Step 7H)
0	---								
2	1,500								
6	1,000	---							
8	1,500	3,000							
10	1,400	2,000							
12	1,500	2,000	---						
14	1,643	2,125	2,500						
16	1,688	2,100	2,250	---					
18	1,778	2,167	2,333	2,500	---				
19	2,158	2,692	3,286	4,667	9,000				
23	2,174	2,588	2,909	3,286	3,600	---			
27	2,630	3,095	3,533	4,000	4,333	5,250	---		
28	3,036	3,591	4,188	4,833	5,300	7,000	14,000		
30	3,000	3,500	4,000	4,500	4,833	5,714	6,333	---	
32	3,313	3,846	4,400	4,938	5,286	6,222	7,000	8,000	
35	3,571	4,103	4,652	5,158	5,471	6,250	6,750	7,000	---
37	4,216	4,839	5,520	6,143	6,526	7,571	8,500	9,429	15,500
40	4,375	4,971	5,607	6,167	6,500	7,353	8,000	8,500	10,000

Exhibit Step 7J - Solutions With Lowest Average Costs for Additional Output

(1) Name of Solution	(2) Component Management Measure Increments	(3) Description	(4) Outputs (HU)	(5) Costs ($)
No Action	No A + No B	no action	0	0
S_2	No A + B_2	maintain water elevation at +120.4 feet	6	6,000
S_5	$A_3 + B_2$	plant 125 shrubs per acre, and, maintain water elevation at +120.4 feet	12	18,000
S_7	$A_3 + B_3$	plant 125 shrubs per acre, and, maintain water elevation at +120.8 feet	16	27,000
S_8	$A_4 + B_3$	plant 175 shrubs per acre, and, maintain water elevation at +120.8 feet	18	32,000
S_{10}	$A_5 + B_3$	plant 350 shrubs per acre, and, maintain water elevation at +120.8 feet	23	50,000
S_{11}	$A_6 + B_3$	plant 550 shrubs per acre, and, maintain water elevation at +120.8 feet	27	71,000
S_{13}	$A_7 + B_3$	plant 750 shrubs per acre, and, maintain water elevation at +120.8 feet	30	90,000
S_{15}	$A_7 + B_4$	plant 750 shrubs per acre, and, maintain water elevation at +121.2 feet	35	125,000
S_{17}	$A_7 + B_5$	plant 750 shrubs per acre, and, maintain water elevation at +121.6 feet	40	175,000

STEP 8 - CALCULATE INCREMENTAL COSTS.

Incremental cost is the difference in cost between two solutions divided by the difference in output between the same two solutions.

Using the set of solutions identified in the Step 7, calculate incremental costs by dividing the difference between two solutions' costs by the difference between the solutions' outputs. The calculation can be expressed as:

$$IC_X = \frac{C_X - C_{X-1}}{O_X - O_{X-1}}$$

Where:
- X = an increment, either of output, a measure, or a plan
- IC_X = incremental cost of X
- C_X = cost of X
- C_{X-1} = cost of previous increment before X
- O_X = output of X
- O_{X-1} = output of previous increment before X

Exhibit Step 8A is a supply schedule of the incremental costs for the lowest average cost solutions identified in the previous step (listed in Exhibit Step 7J). **Exhibit Step 8B** is the same as Exhibit Step 7J, except that the incremental costs have been included in new Column 6. **Exhibit Step 8C** is a bar graph of the incremental costs listed in Exhibit Steps 8A and 8B.

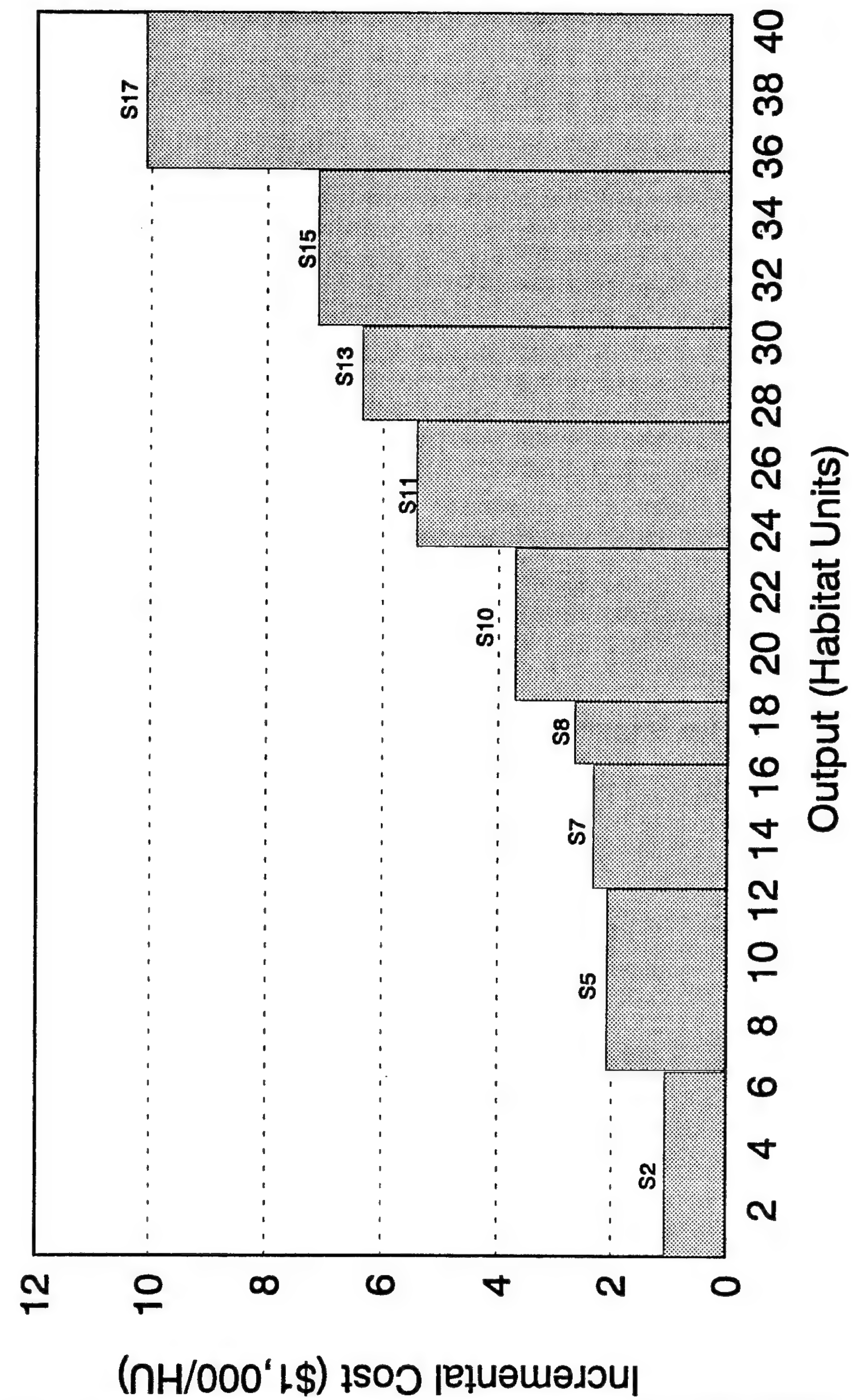
Exhibit Step 8A - Supply Schedule, Incremental Costs

(1) Output (HU)	(2) Cost ($)	(3) Additional Output (HU)	(4) Additional Cost ($)	(5) Incremental Cost ($ per HU)
0	0	---	---	---
6	6,000	6	6,000	1,000
12	18,000	6	12,000	2,000
16	27,000	4	9,000	2,250
18	32,000	2	5,000	2,500
23	50,000	5	18,000	3,600
27	71,000	4	21,000	5,250
30	90,000	3	19,000	6,333
35	125,000	5	35,000	7,000
40	175,000	5	50,000	10,000

Exhibit Step 8B - Solutions With Lowest Average Costs for Additional Output

(1) Name of Solution	(2) Component Management Measure Increments	(3) Description	(4) Outputs (HU)	(5) Costs ($)	(6) Incremental Costs ($ per HU)
No Action	No A + No B	no action	0	0	---
S_2	No A + B_2	maintain water elevation at +120.4 feet	6	6,000	1,000
S_6	A_3 + B_2	plant 125 shrubs per acre, and, maintain water elevation at +120.4 feet	12	18,000	2,000
S_7	A_3 + B_3	plant 125 shrubs per acre, and, maintain water elevation at +120.8 feet	16	27,000	2,250
S_8	A_4 + B_3	plant 175 shrubs per acre, and, maintain water elevation at +120.8 feet	18	32,000	2,500
S_{10}	A_5 + B_3	plant 350 shrubs per acre, and, maintain water elevation at +120.8 feet	23	50,000	3,600
S_{11}	A_6 + B_3	plant 550 shrubs per acre, and, maintain water elevation at +120.8 feet	27	71,000	5,250
S_{13}	A_7 + B_3	plant 750 shrubs per acre, and, maintain water elevation at +120.8 feet	30	90,000	6,333
S_{15}	A_7 + B_4	plant 750 shrubs per acre, and, maintain water elevation at +121.2 feet	35	125,000	7,000
S_{17}	A_7 + B_5	plant 750 shrubs per acre, and, maintain water elevation at +121.6 feet	40	175,000	10,000

Exhibit Step 8C
Incremental Cost



STEP 9 - COMPARE SUCCESSIVE OUTPUTS AND INCREMENTAL COSTS.

The Step 8 exhibits can be used as decision making tools by progressively proceeding through the available levels of outputs and asking if the next level is "worth it" - that is, is the habitat value of the additional HU output in the next available level of output worth its additional monetary cost?

Exhibit Step 9 illustrates the progressive comparison and questioning process. In the first comparison (Exhibit Step 9A), the first level of output is 6 HU, which could be produced at an incremental cost of $1,000 per HU. If decision makers determine that 6 HU's are worth $1,000 apiece, then proceed to the next level of output and repeat the questioning. In this case, the next level of output is 12 HU, which means that an additional 6 HU could be produced at an additional incremental cost of $2,000 per HU (Exhibit Step 9B). Again, if decision makers determine that 6 more HU of output are worth $2,000 apiece, then again proceed to the next level.

This questioning process will tend to continue to conclude that successive levels of output are "worth it" until an unusual increase in incremental costs, beyond the general range of preceding costs, is encountered. For example, incremental costs range between $1,000 per HU to $3,600 per HU for all available levels of output up to 23 HU. An increase to the next available level after 23 HU - to 27 HU - would incur an additional incremental cost of $5,250. This could present decision makers with a situation where the value of increasing outputs to the next available level may need to be explained, supported and considered in more detail than previous increases. In some cases, the additional output - 4 HU in this case - may not be worth the large increase in incremental cost. If a level of output is determined to be "not worth it", then subsequent levels are probably also "not worth it" and the final decision has been reached. However, if the cost is determined to be justified, then the process should proceed to the next available level of output - 30 HU in this case - where an additional 3 HU can be gained at an additional incremental cost of $6,333.

Exhibit Step 9 - Comparison of Outputs and Incremental Costs

Exhibit Step 9A - Are the first 6 HU worth an incremental cost of $1,000 apiece?

(1) Output (HU)	(2) Cost ($)	(3) Additional Output (HU)	(4) Additional Cost ($)	(5) Incremental Cost ($ per HU)
0	0	---	---	---
6	6,000	6	6,000	1,000

Exhibit Step 9B - Are the next 6 HU worth an incremental cost of $2,000 apiece?

(1) Output (HU)	(2) Cost ($)	(3) Additional Output (HU)	(4) Additional Cost ($)	(5) Incremental Cost ($ per HU)
6	6,000	6	6,000	1,000
12	18,000	6	12,000	2,000

Exhibit Step 9C - Are the next 4 HU worth an incremental cost of $2,250 apiece?

(1) Output (HU)	(2) Cost ($)	(3) Additional Output (HU)	(4) Additional Cost ($)	(5) Incremental Cost ($ per HU)
12	18,000	6	12,000	2,000
16	27,000	4	9,000	2,250

Exhibit Step 9D - Are the next 2 HU worth an incremental cost of $2,500 apiece?

(1) Output (HU)	(2) Cost ($)	(3) Additional Output (HU)	(4) Additional Cost ($)	(5) Incremental Cost ($ per HU)
16	27,000	4	9,000	2,250
18	32,000	2	5,000	2,500

Repeat the comparison and questioning - Is the additional HU output worth its incremental cost?

"IS IT WORTH IT?" GUIDELINES.

How Can Uncertainty Be Handled In the Analyses?

See Chapter 4, Question and Answer #13 for a discussion about uncertainty.

Federal planning for water resources development is conducted in accordance with the requirements of the P&G. The P&G provide a decision rule for selecting a recommended plan where both outputs and costs are measured in dollars. This rule states that "the alternative plan with the greatest net economic benefit consistent with protecting the Nation's environment (National Economic Development Plan, NED Plan) is to be selected..." (paragraph 1.10.2). There is **no similar rule** for plan selection where outputs are not measured in dollars, as is the case in planning for restoration and mitigation.

Neither cost effectiveness analysis nor incremental cost analysis include a plan selection rule similar to the traditional NED rule. In the absence of such a decision making rule, neither analysis will tell you what choice to make. However, the information developed by both analyses will help you make better-informed decisions; and, once a decision is made, they will help you to better understand its consequences in relation to your other choices.

While there is no direct parallel to the traditional NED rule for selecting environmental solutions, the following decision making guidelines related to outputs, costs and the display curves can use the results of cost effectiveness and incremental cost analyses to assist in making the "Is it worth it?" decisions:

Output target. If a study has established a specific resource output target to be met, then a decision rule could be developed to meet some portion of that target. For example, if an alternative plan's adverse effect on a cypress-tupelo swamp were to be identified as a loss of 25 HU, then the 100% mitigation target would be 25 HU. The HU target could be marked on a incremental cost bar graph (like Exhibit Step 8C) to provide a picture of the relationship between the target and the possible solutions. This display may be useful to decision makers by focusing the "Is it worth it?" questioning process (Step 9) on the HU target, and asking if the incremental costs of the solutions that lead to the target are worth it. If getting to the HU target is judged to be "worth it", then decision makers may continue to consider solutions beyond the target until it was finally judged to no longer be "worth it" to produce any additional HU output.

A target should be considered a guideline to strive for; in most cases it is not an absolute that must be achieved because it may be unrealistic and may establish expectations that cannot be met. For example, while full restoration of a previous ecological condition may be an ideal target, in many cases it would be both impossible and unacceptable to achieve due to the disruption of human development that would have to be accommodated to achieve it.

In some cases it may be necessary to first produce a minimum base amount of output, and any lesser amount would not be successful. For example, a certain habitat community may require a minimum area of 2,000 acres to support the range of a key species, and any area less than that threshold would not be adequate. In such cases, a minimum target should be considered, and only solutions that would meet or exceed the minimum target output would be considered.

A special "target" is required for adverse effects on wetlands, which are to be "fully mitigated" through actions to avoid, minimize and compensate for unavoidable losses to meet the goal of no net loss of wetlands (Water Resources Development Act of 1990, Section 307(a); ER 1105-2-100, paragraph 7-35g). In this special case, the decision rule would be to mitigate 100% of a wetland loss.

Why Not Choose the Measure or Plan With the Lowest Average Cost?

See Chapter 4, Question and Answer #14 for a discussion about average costs.

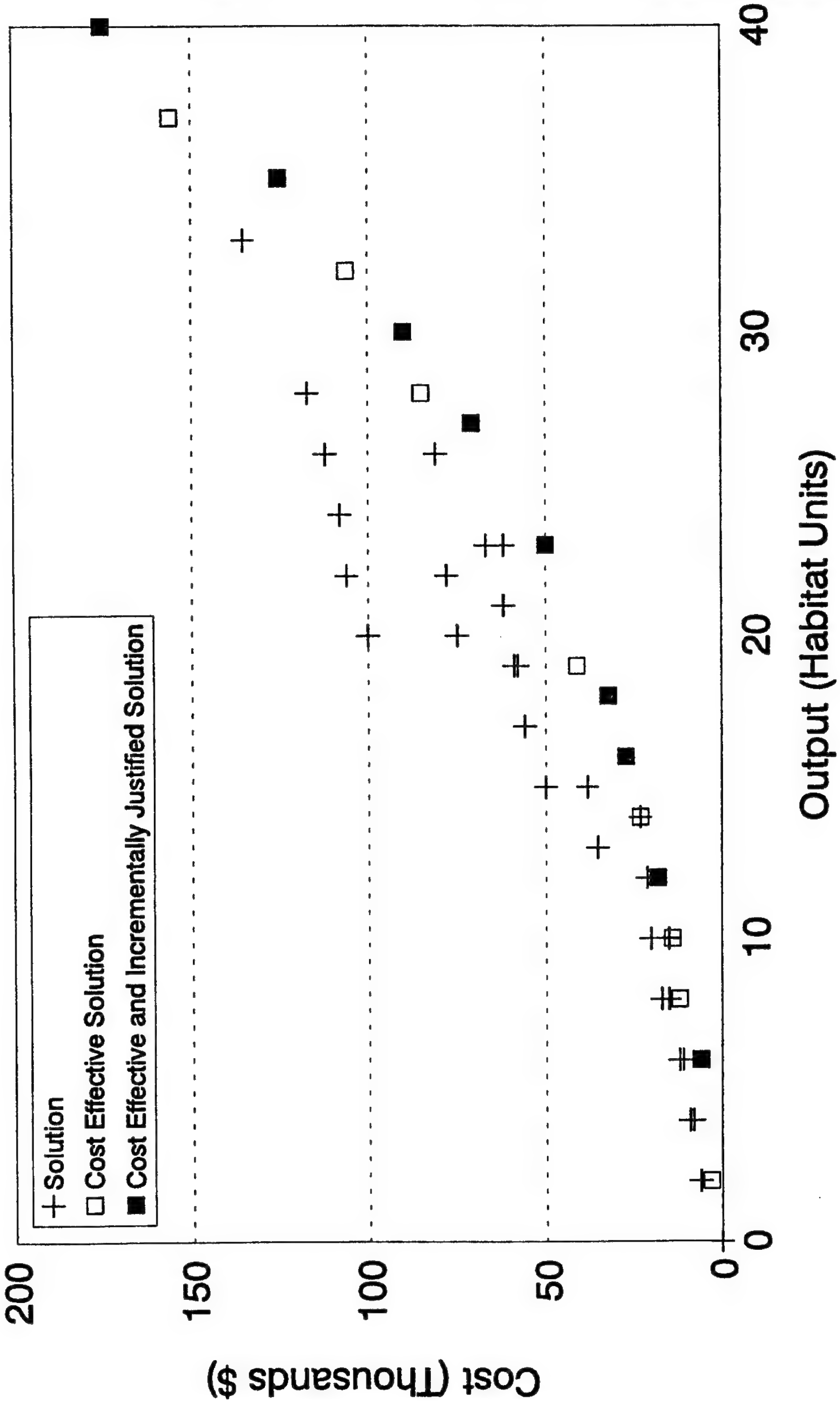
Cost Affordability. If implementation funds are a constraint, then decision makers can review both the cost effectiveness curve and the incremental cost curve for information that will help them judge the "best investment" for the funds available. For example, if only $100,000 is available for a restoration effort, then, by examining the Exhibit Step 5D cost effectiveness curve, decision makers could see that solution S_{13} is the largest solution that could be funded, and that it would produce 30 HU at a cost of $90,000. By further reviewing the Exhibit Step 8B incremental cost bar graph, decision makers could see the incremental cost increases that lead to S_{13}; and they could then ask if, in their judgment, the 30 HU would be the best investment for the funds available.

Curve anomalies. Abrupt changes in an incremental cost curve identify potential decision points for focusing the "Is it worth it?" questioning process. Changes in the curve (or, as used in this procedure, the bars in the incremental cost bar graphs) are referred to as a breakpoint, a spike, a peak, a jump, or the "knee of the curve"; and occur where an incremental cost increases relatively sharply in contrast to preceding or following incremental costs. These points provide decision makers with reasons to question the causes of the changes, and whether the additional incremental costs are "worth it". For example, is there a change in the management measures that comprise the solution, or is a large increase in output or cost due to an increase in the size of a management measure? Such situations may provide persuasive reasons for accepting a seemingly large increase in incremental costs.

The results of cost effectiveness and incremental cost analyses are intended to help decision makers make better informed decisions. However, although you are required to conduct the analyses, there is no requirement to select a solution from the final set of solutions as illustrated in Step 9 of this procedure. **Exhibit A** shows a full range of solutions (from Exhibit Step 3D), and highlights the cost effective solutions (from Exhibit Step 5D) and the incrementally justified solutions (from Exhibit Step 8C).

Other solutions beyond the Step 9 final set will often continue to be considered regardless of their "worthiness" as judged through these analyses. For example, concerns about endangered species, support by a local sponsor or other interest group, cost sharing arrangements, and other factors may lead to the continuing consideration and selection of solutions that may not be the most cost effective or may incur substantial incremental costs. Planners should make decision makers aware of these situations, and present any reasons that may support a decision to pursue an otherwise "unworthy" solution. If decision makers select a solution that the analyses show is not the most cost effective or incrementally justified, then the reasons for such a selection should be clearly explained in the supporting documentation.

Exhibit A
Full Range of Solutions



CHAPTER 4
QUESTIONS AND ANSWERS

The following questions and statements came from Corps field professionals during recent training courses, meetings, reviews and conversations about the application of cost effectiveness and incremental cost analyses in environmental planning. Answers and responses build upon the previous instructions for the analyses, and are intended to both respond to the questions and statements, as well as supplement the instructions with additional explanations.

#1 - WHO DOES THE ANALYSES? - Who conducts the cost effectiveness and incremental cost analyses?

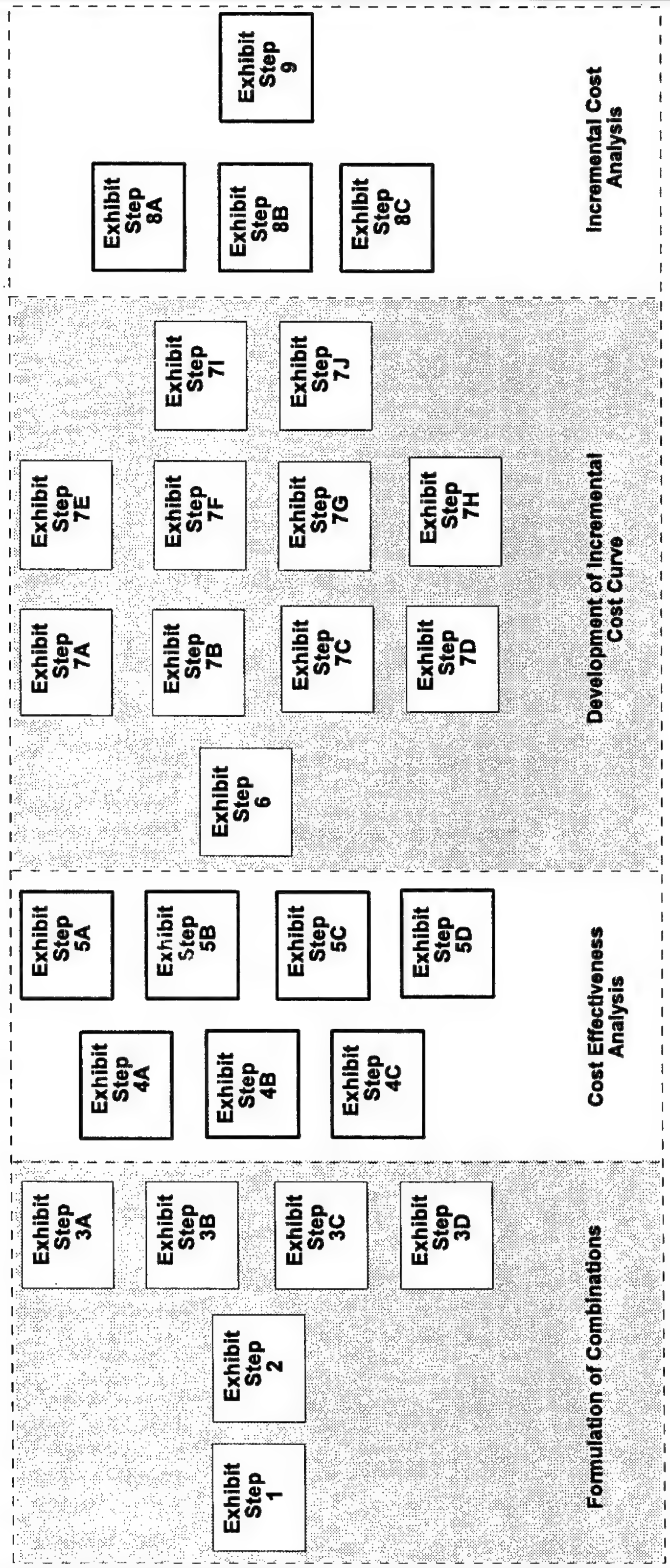
No one professional discipline, or office in the organization, can conduct cost effectiveness and incremental cost analyses in isolation. The nature of the information that drives the analyses, and the ways in which the information is managed and interpreted through the analyses, requires the knowledge and skills of a variety of disciplines. While economists own the concepts behind these analyses and usually have the best initial understanding of how and why the analyses work, ecologists, biologists, and other natural scientists must define the environmental outputs to be analyzed. Similarly, cost engineers, real estate specialists and others estimate implementation costs; which, together with any foregone and incidental economic benefits estimated by economists, comprise the economic effects to be analyzed. Still others, such as hydraulic designers, landscape architects and wildlife managers, are skilled in identifying management measures and different dimensions that can define increments of both measures and alternative plans. Finally, all involved disciplines should provide decision makers with their unique insights in interpreting the results of these analyses; and advice, from their perspective, regarding the "worth it" question.

Cost effectiveness and incremental cost analyses foster learning experiences among all involved professionals in all disciplines. The example exhibits presented in this paper are useful training tools when arranged and displayed on a large board or wall as shown in **Exhibit B**.

#2 - ROLE OF OTHERS - What is the role of other Federal and State agencies and the local cost sharing sponsor in conducting cost effectiveness and incremental cost analyses?

Other agencies, as well as all other interested parties, will continue to play their traditional roles in identifying management measures and alternative plans to be analyzed (all agencies); in evaluating environmental outputs (U.S. Fish and Wildlife Service, National Marine Fisheries Service, state fish and wildlife agencies, and others); and in estimating costs (local cost sharing sponsor, environmental agencies, and others). The representatives of all involved agencies should understand the steps involved in cost effectiveness and incremental cost analyses, and how their contributions - estimates of environmental outputs and costs, and ideas about measures and plans - are used in the analyses. As in the case of the many professional disciplines involved in these analyses, other agencies and interests should also provide decision makers with their unique insights and advice in interpreting results and judging the "worth it" question.

Exhibit B
Display of Example Exhibits



Beyond these traditional roles, other agencies and interests may want to be more active team participants, and their participation should improve their understanding and support for the analyses.

#3 - ANALYSIS TIME AND COST - Cost effectiveness analysis and incremental cost analysis are very time consuming and expensive; the cost of conducting the analyses often will be greater than the cost of any of the projects being analyzed.

The major study cost and time requirements for cost effectiveness and incremental cost analyses are in the set-up of the analyses and not in the analyses themselves. Set-up requirements - for defining alternative increments, management measures and plans; for an evaluation of the alternatives' environmental outputs; and for cost estimates of the alternatives - are largely traditional study requirements. Additional work required solely for the analyses is primarily a function of the number of alternative increments, management measures and alternatives to be analyzed - more alternatives will increase the workload.

In a larger sense, planning for restoration and mitigation - including conducting cost effectiveness and incremental cost analyses - requires a different way of conducting business, not another piece of work on top of business as usual. Planners, biologists, economists and others must truly work together as a team to define reasonable and realistic solutions, and develop estimates of outputs and costs that will lead to more confident decision making. Some initial learning costs can be expected as team members move from their comfortable, traditional professional tasks and relationships to a different way of approaching their work and each other. Investing the same time and funds into a cooperative, interdisciplinary approach will result in better informed decisions.

#4 - LEVEL OF DETAIL - What level of detail is needed in cost effectiveness and incremental cost analyses?

A general rule of thumb is that all planning analyses - including cost effectiveness and incremental cost analyses - should be developed in enough detail to support making the decision at hand. For example, if a decision is to select from among a series of alternative lake water elevations, and elevation differences of a few inches result in hundreds of acres of land being dry or inundated, then detailed topographic information may be required. However, if it is adequate to know that two alternative plans would cost about the same, but that one would probably produce several times as many habitat units as the other, then an obviously lesser level of detail would be necessary to chose between them. Each study must determine the level of detail adequate to meet its unique decision making needs.

Concerns about level of detail may arise in two main areas in cost effectiveness and incremental cost analyses:

Outputs and costs. Whether they were developed on the back of an envelope in an afternoon or resulted from a year's modeling, estimates of environmental outputs and cost estimates should reflect about the same level of confidence and effort in their development.

Since the cost effectiveness and incremental cost analyses will be only as reliable and revealing as the least-developed data, output and cost estimates should be comparable.

Increments/measures/plans. Increasing the level of definition - and therefore the number - of management measure increments, management measures, and alternative plans will rapidly increase the number of solutions to be analyzed (see #9 and #10 below). The number of increments/measures/plans considered should be adequate to reveal meaningful changes in environmental outputs and costs, but reasonable enough such that the study is not overwhelmed by analytical demands.

The question of a proper level of detail is also related to risk and uncertainty (see #13 below), with more detail generally reducing both the uncertainty of results and risk associated with estimates that may be largely incorrect.

#5 - HABITAT UNITS - Are habitat units (HU) the only type of environmental output that can be used in cost effectiveness and incremental cost analyses?

No. An output is a type of result - a "benefit" - that is to be produced by a solution that is intended to achieve a planning objective. Any given planning objective may result in many different types of output. An output's unit of measurement must be subject to the mathematical calculations performed in cost effectiveness and incremental cost analyses. Ordinal units of measurement (1st, 2nd, 3rd...) cannot be used in these analyses. However, cardinal units of measurement, such as numbers of habitat units, can be used.

Habitat units are a product of the "Habitat Evaluation Procedures" (U.S. Fish and Wildlife Service 1980; referred to as "HEP") as well as several other habitat-based evaluation methodologies derived from HEP. While habitat units are acceptable for use in cost effectiveness and incremental cost analyses, other units of measurement may be used, such as acres of a defined type of resource, species population counts, productivity (pounds per acre, for example), and diversity (number of plants or animals per acre, for example). In cases where there are different and multiple outputs (see #7 below), a useful measurement may be percent increases or percent achievement of an objective. Each study must determine the best way to measure environmental outputs to meet its unique decision making needs.

#6 - SPECIES - Are cost effectiveness and incremental cost analyses only applicable to planning for individual fish and wildlife species?

No. Cost effectiveness and incremental cost analyses are applicable to a full range of environmental planning concerns, ranging from individual species, through communities, to ecosystems. Regardless of the level at which you approach the analysis, the critical concern is to select and use a unit of measurement that accurately reflects conditions and changes at that level.

#7 - MULTIPLE AND DIFFERENT OUTPUTS - What about the "apples and oranges" problem where there is more than one environmental output, and the outputs are different and can't be added?

A study may use multiple and different environmental outputs if it has more than one objective that is not evaluated in monetary terms. For example, a study may have objectives of restoring a littoral community, as measured in community-based habitat units (HU); and reducing the amount of phosphorus in a tributary stream, as measured in milligrams of phosphorus per liter of water sampled (mg/l). In the absence of a single, common environmental measurement unit, two analyses - one based on changes in HU and another based on changes in mg/l of phosphorus - are necessary.

Studies with multiple and different environmental outputs are, consequently, more problematic for decision makers. Where alternative plans affect objectives similarly (for example: HU and mg/l either both improve or are both degraded), then the comparison and trade-offs between them may be relatively straightforward. However, where alternative plans affect the objectives differently, then judgments are necessary to compare and make trade-offs between them. While there are many approaches that can be used in making such decisions, there is no single best approach.

Planners must be aware that multiple and different environmental outputs will probably increase a study's workload and complicate decision making. However, in some cases it will not be possible to reflect an area's environmental problems and opportunities in a single objective or with a single measurement unit, and multiple outputs will be necessary. In these situations, cost effectiveness and incremental cost analyses do not, in themselves, complicate planning, but rather develop more information to help address an already complicated analysis.

#8 - WHAT'S AN INCREMENT? - Increments usually refer to parts of a plan or project, and now there's incremental costs; just what is an increment?

The word "increment" is used to qualify several concepts traditionally used in planning water resources projects: increments of cost, increments of output, incremental costs, increments of a management measure, and increments of an alternative plan (or project). When used in the context of cost or output, "increment" refers to the difference in cost or output between two solutions. When used in the context of a management measure or alternative plan, "increment" refers to the size of the measure or plan.

Increment of cost. An increment of cost is the difference in cost between two measure increments or plan increments. An increment of cost is expressed in dollars. For example, if the first measure increment of management measure A costs $6,000, and the second measure increment of management measure A costs $8,000, the increment of cost between them is $2,000.

Increment of output. An increment of output is the difference in the output between two measure increments or plan increments. An increment of output is expressed in the unit of measurement used for environmental analysis, such as habitat units (HU). For example, if the first measure increment of management measure A produces 2 HU, and the second measure increment of management measure A produces 5 HU, the increment of output between them is 3 HU.

Incremental cost. For the purpose of this procedure, incremental cost is defined as the difference in cost between two measure increments or plan increments (increment of cost) divided by the difference in output between the same two measure or plan increments (increment of output). Incremental cost is expressed as a ratio of dollars per unit of environmental output, such as dollars per habitat unit ($/HU). See the discussion in Step 8 about the calculation of incremental cost.

Increment of a management measure. An environmental management measure is one or more management **feature** or **activity**, at a geographic **site**, that is intended to cause a desirable change in an environmental output. Features and activities are the individual techniques, methods and other elements that can be implemented at a site to cause a change in environmental output. In general, features are structural elements requiring some type of site construction; and activities are nonstructural, ongoing (either continuing or periodic) actions.

Management measures may be described in a range of dimensions that would produce different levels of output and cost. Different dimensions have traditionally been called "increments" in the engineering practice (increasing heights of a levee, for example).

Dimensions refer to quantities, amounts, number counts or other characteristics used to size a management measure, and are equally applicable to sites, features and activities. Different dimensions modify, rather than define, different management measures; and result in different outputs and costs for a given measure. Key questions to consider in developing a scale of dimensions are:

How much? How many?
What size? How large? How small?
How often? What duration?

Sites are sized based on areal measurements. For example, a "grazing pasture" could be sized in increments of the area of pasture to be managed (0.5 acre, 1 acre, 1.5 acres...).

Features may be sized in many dimensions. For example, a retaining dike that would pond water to restore a wetland could be sized in increments of the structure's height (+3.0 feet, + 3.5 feet, +4.0 feet...). More nontraditional, environmentally-oriented features will often have other sizing dimensions. For example, "brush piles" could be sized by density in increments of the number of brush piles that could be built (1 pile/acre, 2 piles/acre, 3 piles/acre...).

Activities may be sized by their frequency (irrigating every other day, irrigating every third day, irrigating every fourth day...), duration (2 week dredging window, 3 week dredging window, 4 week dredging window...), or other dimension.

In Exhibit Step 1, the three management measures used in this procedure's case example are listed in Column 1, and the measures' increments are listed in Column 2.

Many of the variables used in habitat-based analytical techniques (such as HEP) can be used to define the dimensions of management measures. For example, if "percent herbaceous canopy cover" is a variable for a target species, and if planting herbaceous vegetation were being considered as a management measure,

then the measure could be sized in increments of the variable, such as: 30% herbaceous canopy cover, 40% herbaceous canopy cover, 50% herbaceous canopy cover, and so forth.

Minimum and maximum sizes of a management measure are often important considerations, and could be a basis to bound the range of a measure's increments. Again, habitat-based analytical techniques, particularly their suitability index models, provide information that is useful in bounding the range of increments to be considered.

Some management measures may be "either-or" measures that are not possible, or reasonable, to size, and there is only one increment to consider. For example, although different sized areas may be considered, natural revegetation may be a single-increment measure (either it does or it doesn't naturally revegetate). Administrative actions, such as requiring a permit or a license, may also be single-increment measures (for example, either a license is required or it isn't). Equipment is often available in only a single size (for example: a water pump with a fixed pumping capacity), and therefore is a single-increment measure.

The most important consideration in defining an array of dimensions is that changes in a management measure's size should result in changes in the measure's output, or its cost, or both.

Increment of an alternative plan. An alternative plan is one or a combination of management measures. A plan's measures are intended to collectively act together to cause a desirable change in output. Like management measures, alternative plans may be sized to produce different amounts of output at different costs. While a management measure is sized in different dimensions, an alternative plan is sized by changing the size and mix of measures that comprise the plan.

#9 - HOW MANY INCREMENTS? - Cost effectiveness and incremental cost analyses become more complicated, more costly, and more time consuming as more increments of management measures and alternative plans are included; how many increments are needed?

As noted in Step 3, the number of solutions - and, consequently, the number of output and cost estimates - rapidly increase as the numbers of management measures and their increments increase. Therefore, the numbers of measures and their increments should be kept to a minimum to minimize the cost and time needed for analyses.

There are no universal rules for determining the number of increments of management measures or alternative plans that should be considered in every case - the number that should be defined is a matter of judgment. However, that judgment should result in a set of increments that are:

Meaningful. For example, increments of fenced-in area in 0.01 of an acre, or in 10,000 acres, are probably not correctly sized and would result in too many or too few solutions for most analyses. Also, there is no reason, beyond ease of comparisons and symmetry, that increments must be identical in size. For example, increments of 10, 25, 50 and 100 units may be used in the same analysis if it makes sense to do so.

Practical. Some measures or plans may only be implementable over very few increments. For example, certain types of equipment, such as water pumps, may only be able to be sized based on a limited available selection of sizes.

Revealing. The number of increments should be adequate to reveal significant changes in environmental outputs and costs. A cost effectiveness curve or an incremental cost graph reflecting only two measure or plan increments is usually not revealing, and therefore not helpful, for decision making.

Reasonable. The number of increments should strike a reasonable balance between the needs and constraints of the analysis and the burdens (cost, time, and understanding) imposed by large numbers of solutions that are not sufficiently differentiated to make a difference in decision making. In many cases, only a few solutions will be reasonable. Additional increments, measures or alternative plans should not be artificially created simply for the sake of analysis.

#10 - NUMBER OF COMBINATIONS - In a study that's looking at many management measures, as well as different sized increments of some of those measures, a very large number of combinations may be possible; must every combination always be identified and analyzed?

No. Again, as noted in Step 3, the number of combinations - and, consequently, the number of output and cost estimates - rapidly increases as the numbers of management measures and their increments increase. For example, a simple case reveals the following numbers of combinations for a set of management measures:

If the number of management measures is:	Then there are this many combinations of those measures:
1	1
2	3
3	7
4	15
5	31
6	63
7	127
8	255
9	511
10	1023

(Note: This example assumes that all measures can be combined, that each measure has only one increment of size, and that the order in which measures are implemented is irrelevant.)

Two recent studies illustrate the range of combinations possible in plan formulation. First, in the relatively small Bussey Lake restoration, four management measures were considered: aeration (one size of pump considered), substrate improvement (one size area considered), harvesting (five different sized areas

considered), and dredging (seven different volumes of material considered). These measures and their increments produced 192 combinations (U.S. Army Corps of Engineers, Institute for Water Resources 1993a). On a much larger scale, an analysis of mitigation options for chinook salmon and steelhead stocks in the mid-Columbia River region was faced with the potential to analyze a staggering 7 X 10^{47} possible combinations of passage, propagation and harvest measures (Paulsen et al. 1993).

Obviously, consideration of the full range of combinations and the resulting analytical burden could easily overwhelm a study. While the best way to accommodate this problem will be unique to each study, the following points should be considered:

- The number of possible combinations can be limited early by simply limiting the number of management measures and their increments that are included for analysis. Where there are a large number of possible measure increments, the analyses could be initially limited to analyzing only the largest and smallest increments ("high-low" analysis) to scope the range of costs and outputs; subsequent iterations could then be conducted for the more promising increments. Management measures should be capable of producing the types of changes desired, technically possible, and otherwise reasonable. See the previous question and answer section for a discussion of how many increments should be considered.

- While solutions should be limited to those that are reasonable, the danger in judging "reasonableness" too early is that promising solutions - perhaps the "best" solution - may be overlooked. The desire to minimize the analytical burden must be weighed against the need to give fair consideration to a full range of solutions.

- Technology is available to speed and ease the development and analysis of a large number of combinations. The Bussey Lake analysis of 192 combinations used the commonly available LOTUS 1-2-3 (®). The Columbia River salmon and steelhead analysis used several unique and complex models, including a linear programming framework, to search and select solutions. An automated version of the steps presented in this paper is being developed as a part of the Evaluation of Environmental Investments Research Program, and is expected to be available as a draft program in 1995.

- Since any given combination is possible to identify, it is possible (although perhaps not likely) that any combination could be suggested as an alternative plan at any time during the course of a study. While it may not be desirable or practical to analyze all possible combinations, planners should at least recognize the potentially large number of combinations that could be developed, and understand the implications of including or excluding any particular set of combinations.

#11 - RESTORATION AND MITIGATION - Are cost effectiveness and incremental cost analyses to be used in restoration planning, or mitigation planning, or both?

Both. Cost effectiveness and incremental cost analyses are applicable equally to restoration and mitigation planning.

#12 - SEQUENCING - How do cost effectiveness and incremental cost analyses fit with mitigation "sequencing"?

Mitigation planning may proceed through at least three repetitions (often called "iterations") of the planning process to sequentially meet three different mitigation objectives: **avoid** adverse effects, **minimize** unavoidable adverse effects, and **compensate** for any remaining unavoidable adverse effects. Conducting iterations to meet these objectives in this order is called **sequencing**. Cost effectiveness and incremental cost analyses can be applied in each of these three iterations in mitigation planning.

Initially, alternative management measures and plans that would totally avoid the adverse effect to be mitigated can be evaluated and analyzed to identify the least cost way to avoid the effect (cost effectiveness analysis). Incremental cost analysis is not applicable in avoidance planning since only one level of output (no effect) is considered.

Planning to minimize and compensate for unavoidable adverse effects may examine both the array of least cost alternative measures and plans that would minimize, and then compensate for, a range of adverse output (cost effectiveness analysis); as well as the incremental costs between first the minimizing solutions and then the compensating solutions. When decision makers compare and select among solutions that would minimize or compensate for an adverse effect, the "worth it" question in interpreting incremental costs of environmental outputs is relevant.

At this time, the Corps requires the sequencing approach to be used only for regulatory actions, and sequencing is not required for Corps project planning studies.

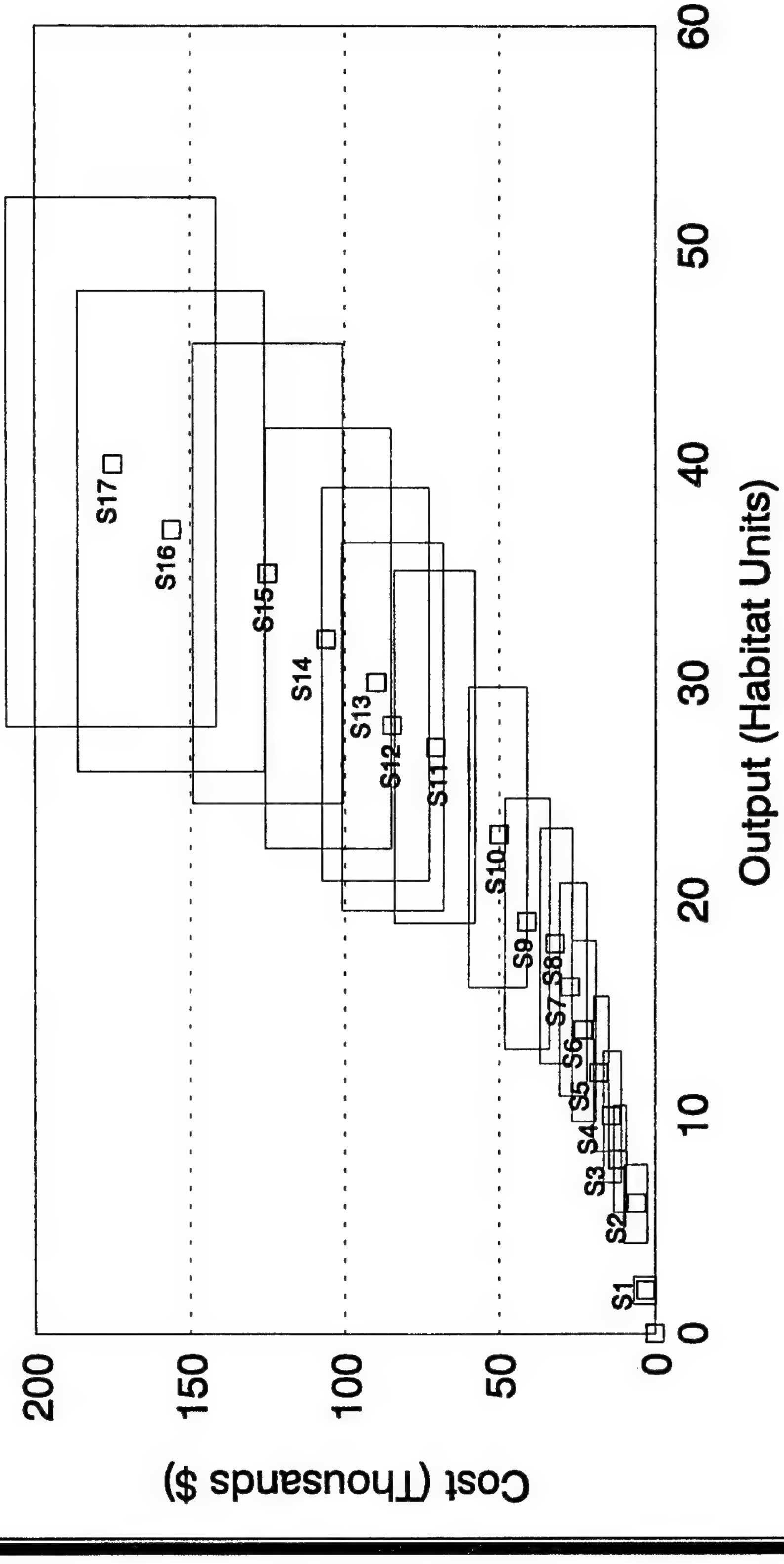
#13 - UNCERTAINTY - How can uncertainty in the data and assumptions used in the analyses be handled?

Recent experience has shown that "the cost effectiveness approach... implies a degree of certainty in the economic costs and biological effectiveness that simply does not exist. Points on the [cost effectiveness] figure would be better defined as a box that reflects the uncertainty associated in both the economic costs or the biological effectiveness of the different alternatives" (Woodruff and Huppert, 1993).

Exhibit C is an example of how the cost effectiveness graph (Exhibit Step 5D) could be expanded to show the uncertainty of the estimated outputs and costs. In this example, outputs were judged to range from 30% above to 30% below their estimated levels, and costs were judged to range from 20% above to 20% below their estimated levels. The cost effective points from Exhibit Step 5D are surrounded by boxes that represent these ranges of uncertainty associated with each estimate. This is a more realistic picture of the effects of solutions.

See Supplement I to the P&G for a general discussion of risk, uncertainty and sensitivity analysis in water resources planning, including the sources of uncertainty that should be accounted for in cost effectiveness and incremental cost analyses.

Exhibit C
Uncertainty of Outputs and Costs



#14 - AVERAGE COSTS - Why not choose the measure or plan with the lowest average cost?

For many, the idea of calculating average costs and then selecting the solution with the lowest average cost is a familiar, straightforward and natural first response for decision making. This is the approach many of us use every day, for example, to choose among several brands of a product at the supermarket.

First, you **can**, of course, calculate the average cost (or "unit cost") for a solution's output by simply dividing cost by output. Second, you **can** use "lowest cost" (as either lowest **total** cost or lowest **average** cost) as a selection rule for selecting among a set of solutions. In fact, Steps 4 and 5 of the process presented in this paper use lowest total cost to eliminate inefficient and ineffective solutions, and Steps 6 and 7 use repetitive selection of lowest average cost solutions as a way to screen solutions.

Additionally, if you have a defined target level of output (mitigate 100% of a wetland loss, for example), and if you interpret the target as absolute and the only acceptable level of output, then you may also use "lowest cost" as the selection rule because the only solutions you will consider are those that will produce that defined level of output. In this case, selection of the lowest cost solution (either lowest average cost or lowest total cost) makes economic sense.

However, whether or not you have a defined target level of output, using "lowest cost" as the **only** selection rule may lead you to miss a valid opportunity to provide more environmental output - you could overlook important information and inadvertently shortchange the environment. Looking only at the cost side ignores the value of the environmental output being produced. For example, given the solutions listed in Exhibit Step 8B, if you make a decision based on lowest average cost, you will select solution S_2 because it has the lowest average cost of $1,000 per HU (column 5 costs divided by column 4 outputs). Such a decision would preclude any further consideration of the additional opportunities shown in the Exhibit Step 8C graph, which provides a basis for examining greater levels of output.

More dramatically, **Exhibit D** illustrates the case where, with little increase in cost beyond the "lowest average cost" solution, you could gain a substantial increase in environmental output. If you limit your considerations to only total or average costs, then this type of information is not available, and decision makers will never be aware of any larger levels of environmental output that may truly be "worth it".

This notion about how average costs are used is not new, but is the same conceptual approach used in traditional planning for flood control and navigation. In such planning, a final solution is selected based on having the "greatest net economic benefit" and not on the greatest benefit-cost ratio (which is a form of average cost). For example, given two solutions, A and B, with economic costs and benefits as described in **Exhibit E**, the selected solution would not be Plan A, which has the lowest average cost (biggest benefit-cost ratio), but rather Plan B because it maximizes net benefits. The same principle applies to decision making where benefits are not measured monetarily, including decision making for environmental restoration and mitigation. For additional information about average costs and cost analysis in general see the Overview Manual for Conducting National Economic Development Analysis (U.S. Army Corps of Engineers, Institute for Water Resources 1991b).

Exhibit D - Lowest Average Cost Solution

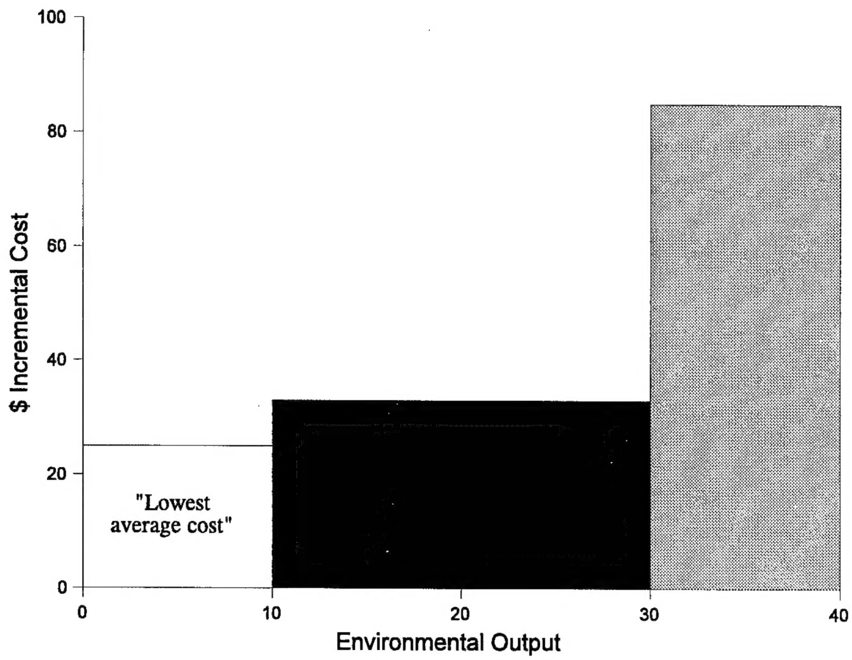


Exhibit E - Benefit/Cost Ratio Vs. Net Benefits

SOLUTION	$ COST	$ BENEFITS	BENEFIT/COST RATIO ("AVERAGE COST")	NET $ BENEFITS
A	$100,000	$200,000	2.0	$100,000
B	$150,000	$260,000	1.7	$110,000

#15 - FEWER STEPS - Is it always necessary to complete all nine steps?

No. In some cases steps can be skipped. As discussed in the Summary, the formulation of combinations (Steps 1 - 3) and the screening analysis (Steps 6 - 7) tasks may not be necessary for your study. Also, if Step 4, 5, 6 or 7 eliminate all but one solution, then you should proceed to the Step 9 "worth it" question.

REFERENCES

Executive Order 12893, Principles for Federal Infrastructure Investments. 1994. Washington, DC.

National Performance Review. 1993a. Creating a Government that Works Better & Costs Less, Report of the National Performance Review. Washington, DC.

National Performance Review. 1993b. Creating Government that Works Better & Costs Less, Reinventing Environmental Management, Accompanying Report of the National Performance Review. Washington, DC.

Paulsen, C.M., J.B. Hyman, and K. Wernstedt. 1993. Above Bonneville Passage and Propagation Cost-Effectiveness Analysis. Report (Project Number 85-087-01) to Bonneville Power Administration, Washington, DC.

U.S. Army Corps of Engineers. 1988. EC 1105-2-185, Fish and Wildlife Mitigation Planning: Incremental (Marginal) Cost Analysis. Washington, DC.

U.S. Army Corps of Engineers. 1990. ER 1105-2-100, Guidance for Conducting Civil Works Planning Studies. Washington, DC.

U.S. Army Corps of Engineers. 1991. Policy Guidance Letter No. 24, Restoration of Fish and Wildlife Habitat Resources. Washington, DC.

U.S. Army Corps of Engineers. 1994. EC 11-2-163, Annual Program and Budget Request for Civil Works Activities, Corps of Engineers, Fiscal Year 1996. Washington, DC.

U.S. Army Corps of Engineers, Institute for Water Resources. 1991a. Economic and Environmental Considerations for Incremental Cost Analysis in Mitigation Planning. IWR Report 91-R-1. Prepared by Greeley-Polhemus Group, Inc. for the Institute for Water Resources, Alexandria, Virginia.

U.S. Army Corps of Engineers, Institute for Water Resources. 1991b. National Economic Development Manual - Overview Manual for Conducting National Economic Development Analysis. IWR Report 91-R-11. Prepared by Greeley-Polhemus Group, Inc. for the Institute for Water Resources, Alexandria, Virginia.

U.S. Army Corps of Engineers, Institute for Water Resources. 1992. Incremental Cost Analysis Primer for Environmental Resources Planning (draft). Prepared by Greeley-Polhemus Group, Inc. for the Institute for Water Resources, Alexandria, Virginia.

U.S. Army Corps of Engineers, Institute for Water Resources. 1993a. Bussey Lake: Demonstration Study of Incremental Analysis in Environmental Planning. IWR Report 93-R-16. Prepared by Bruce D. Carlson with Gary D. Palesh for the Institute for Water Resources, Alexandria, Virginia.

U.S. Army Corps of Engineers, Institute for Water Resources. 1993b. Environmental Activities in Corps of Engineers Water Resources Programs: Charting a New Direction. IWR Report 93-PS-1. Prepared by Leonard Shabman for the Institute for Water Resources, Alexandria, Virginia.

U.S. Fish and Wildlife Service. 1980. Habitat Evaluation Procedures (HEP), Ecological Services Manual 102. Washington, DC.

U.S. Water Resources Council. 1983. Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. Washington, DC.

Water Resources Development Act of 1986, Public Law 99-662. 1986. Washington, DC.

Water Resources Development Act of 1990, Public Law 101-640. 1990. Washington, DC.

Woodruff, E.J. and D.D. Huppert. 1993. Role of Economics in Endangered Species Act Activities Related to Snake River Salmon.

Yoe, C. 1993. Incremental Cost Analysis: A Tool for Environmental Planning. Review draft discussion paper for Council on Environmental Quality, Washington, DC.